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Title of the Invention

A PRINTHEAD ASSEMBLY FOR A PRINT ON DEMAND DIGITAL CAMERA SYSTEM

Field of the Invention

The present invention relates substantially to the concept of a disposable camera having instant printing capabilities and in particular, discloses a printhead assembly for a digital camera system.

Background of the Invention

Recently, the concept of a "single use" disposable camera has become an increasingly popular consumer item. Disposable camera systems presently on the market normally include an internal film roll and a simplified gearing mechanism for traversing the film roll across an imaging system including a shutter and lensing system. The user, after utilizing a single film roll returns the camera system to a film development center for processing. The film roll is taken out of the camera system and processed and the prints returned to the user. The camera system can then be re-manufactured through the insertion of a new film roll into the camera system, the replacement of any worn or wearable parts and the re-packaging of the camera system in accordance with requirements. In this way, the concept of a single use "disposable" camera is provided to the consumer.

Recently, a camera system has been proposed by the present applicant which provides for a handheld camera device having an internal print head, image sensor and processing means such that images sense by the image sensing means, are processed by the processing means and adapted to be instantly printed out by the printing means on demand. The proposed camera system further discloses a system of internal "print rolls" carrying print media such as film on to which images are to be printed in addition to ink to supplying the printing means for the printing process. The print roll is further disclosed to be detachable and replaceable within the camera system.

Unfortunately, such a system is likely to only be constructed at a substantial cost and it would be desirable to provide for a more inexpensive form of instant camera system which maintains a substantial number of the quality aspects of the aforementioned arrangement.

It would be further advantageous to provide for the effective interconnection of the sub components of a camera system.

Summary of the Invention

According to a first aspect of the invention, there is provided a printhead assembly for a

camera system having a chassis and a platen assembly that is mountable on the chassis, the platen assembly being configured to support passage of a print medium along a printing path, the printhead assembly comprising

an ink reservoir assembly that is mountable on the chassis and defines at least three ink reservoirs in which differently colored inks are received, the ink reservoir assembly defining an outlet;

a guide assembly that is positioned in the ink reservoir assembly to define at least three discrete ink paths that open at the outlet; and

at least one printhead ~~chip~~integrated circuit that is positioned in the outlet to span the printing path, the, or each, printhead ~~chip~~integrated circuit defining at least three sets of inlet apertures, each set of inlet apertures being aligned with a respective ink path.

The ink reservoir assembly may define three ink reservoirs and the guide assembly may define three discrete ink paths.

Both the ink reservoir assembly and the guide assembly may be elongate to span the printing path. The ink reservoir assembly may include an elongate base member and an elongate cover member, the cover member having a roof wall, a pair of opposed side walls and a pair of spaced inner walls, the side walls and the inner walls depending from the roof wall and being generally parallel to each other and the base member having a floor and a pair of opposed end walls and defining an elongate opening in which the printhead ~~chip~~integrated circuits are mounted, the guide assembly being interposed between lower ends of the inner walls and the floor.

The guide assembly may include a pair of guide walls that extend from respective lower ends of the inner walls inwardly towards the elongate opening to define the three distinct ink paths that terminate at respective sets of inlet apertures of the printhead ~~chip~~integrated circuits.

The base member, the cover member and the guide assembly may be molded of a plastics material.

One of the end walls may define a number of air inlet openings that are treated to be hydrophobic to permit the ingress of air into the ink reservoirs as ink is fed from the ink reservoirs and to inhibit the egress of ink.

A sponge-like member may be positioned in each ink reservoir to store the ink while inhibiting agitation of ink during general use of the camera system.

The invention extends to a camera system that includes a printhead assembly as described above.

In accordance with a second aspect of the present invention, there is provided in a camera system comprising: an image sensor device for sensing an image; a processing means

for processing the sensed image; a print media supply means for the supply of print media to a print head; a print head for printing the sensed image on the print media stored internally to the camera system; a portable power supply interconnected to the print head, the sensor and the processing means; and a guillotine mechanism located between the print media supply means and the print head and adapted to cut the print media into sheets of a predetermined size.

Further, preferably, the guillotine mechanism is detachable from the camera system. The guillotine mechanism can be attached to the print media supply means and is detachable from the camera system with the print media supply means. The guillotine mechanism can be mounted on a platen unit below the print head.

Brief Description of the Drawings

Notwithstanding any other forms which may fall within the scope of the present invention, preferred forms of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 illustrates a front perspective view of the assembled camera of the preferred embodiment;

Fig. 2 illustrates a rear perspective view, partly exploded, of the preferred embodiment;

Fig. 3 is a perspective view of the chassis of the preferred embodiment;

Fig. 4 is a perspective view of the chassis illustrating mounting of electric motors;

Fig. 5 is an exploded perspective of the ink supply mechanism of the preferred embodiment;

Fig. 6 is rear perspective of the assembled form of the ink supply mechanism of the preferred embodiment;

Fig. 7 is a front perspective view of the assembled form of the ink supply mechanism of the preferred embodiment;

Fig. 8 is an exploded perspective view of the platen unit of the preferred embodiment;

Fig. 9 is a perspective view of the assembled form of the platen unit;

Fig. 10 is also a perspective view of the assembled form of the platen unit;

Fig. 11 is an exploded perspective view of the printhead recapping mechanism of the preferred embodiment;

Fig. 12 is a close up exploded perspective of the recapping mechanism of the preferred embodiment;

Fig. 13 is an exploded perspective of the ink supply cartridge of the preferred embodiment;

Fig. 14 is a close up perspective, view partly in section, of the internal portions of the ink supply cartridge in an assembled form;

Fig. 15 is a schematic block diagram of one form of ~~chip~~integrated circuit layer of the image capture and processing ~~chip~~integrated circuit of the preferred embodiment;

Fig. 16 is an exploded view perspective illustrating the assembly process of the preferred embodiment;

Fig. 17 illustrates a front exploded perspective view of the assembly process of the preferred embodiment;

Fig. 18 illustrates a perspective view of the assembly process of the preferred embodiment;

Fig. 19 illustrates a perspective view of the assembly process of the preferred embodiment;

Fig. 20 is a perspective view illustrating the insertion of the platen unit in the preferred embodiment;

Fig. 21 illustrates the interconnection of the electrical components of the preferred embodiment;

Fig. 22 illustrates the process of assembling the preferred embodiment; and

Fig. 23 is a perspective view further illustrating the assembly process of the preferred embodiment.

Description of Preferred and Other Embodiments

Turning initially simultaneously to Fig. 1 and Fig. 2 there are illustrated perspective views of an assembled camera constructed in accordance with the preferred embodiment with Fig. 1 showing a front perspective view and Fig. 2 showing a rear perspective view. The camera 1 includes a paper or plastic film jacket 2 which can include simplified instructions 3 for the operation of the camera system 1. The camera system 1 includes a first "take" button 4 which is depressed to capture an image. The captured image is output via output slot 6. A further copy of the image can be obtained through depressing a second "printer copy" button 7 whilst an LED light 5 is illuminated. The camera system also provides the usual view finder 8 in addition to a CCD image capture/lensing system 9.

The camera system 1 provides for a standard number of output prints after which the camera system 1 ceases to function. A prints left indicator slot 10 is provided to indicate the number of remaining prints. A refund scheme at the point of purchase is assumed to be operational for the return of used camera systems for recycling.

Turning now to Fig. 3, the assembly of the camera system is based around an internal chassis 12 which can be a plastic injection molded part. A pair of paper pinch rollers 28, 29 utilized for decurling are snap fitted into corresponding frame holes eg. 26, 27.

As shown in Fig. 4, the chassis 12 includes a series of mutually opposed prongs eg. 13,

14 into which is snapped fitted a series of electric motors 16, 17. The electric motors 16, 17 can be entirely standard with the motor 16 being of a stepper motor type. The motor 16, 17 include cogs 19, 20 for driving a series of gear wheels. A first set of gear wheels is provided for controlling a paper cutter mechanism and a second set is provided for controlling print roll movement.

Turning next to Figs. 5 to 7, there is illustrated an ink supply mechanism 40 utilized in the camera system. Fig. 5 illustrates a back exploded perspective view, Fig. 6 illustrates a back assembled view and Fig. 7 illustrates a front assembled view. The ink supply mechanism 40 is based around an ink supply cartridge 42 which contains printer ink and a print head mechanism for printing out pictures on demand. The ink supply cartridge 42 includes a side aluminium strip 43 which is provided as a shear strip to assist in cutting images from a paper roll.

A dial mechanism 44 is provided for indicating the number of "prints left". The dial mechanism 44 is snap fitted through a corresponding mating portion 46 so as to be freely rotatable.

As shown in Fig. 6, the mechanism 40 includes a flexible PCB strip 47 which interconnects with the print head and provides for control of the print head. The interconnection between the Flex PCB strip and an image sensor and print head ~~chip~~integrated circuit can be via Tape Automated Bonding (TAB) Strips 51, 58. A moulded aspherical lens and aperture shim 50 (Fig. 5) is also provided for imaging an image onto the surface of the image sensor ~~chip~~integrated circuit normally located within cavity 53 and a light box module or hood 52 is provided for snap fitting over the cavity 53 so as to provide for proper light control. A series of decoupling capacitors eg. 34 can also be provided. Further a plug 45 (Fig. 7) is provided for re-plugging ink holes after refilling. A series of guide prongs eg. 55-57 are further provided for guiding the flexible PCB strip 47.

The ink supply mechanism 40 interacts with a platen unit 60 which guides print media under a printhead located in the ink supply mechanism. Fig. 8 shows an exploded view of the platen unit 60, while Figs. 9 and 10 show assembled views of the platen unit. The platen unit 60 includes a first pinch roller 61 which is snap fitted to one side of a platen base 62. Attached to a second side of the platen base 62 is a cutting mechanism 63 which traverses the platen unit 60 by means of a rod 64 having a screw thread which is rotated by means of cogged wheel 65 which is also fitted to the platen base 62. The screw threaded rod 64 mounts a block 67 which includes a cutting wheel 68 fastened via a fastener 69. Also mounted to the block 67 is a counter actuator which includes a pawl 71. The pawl 71 acts to rotate the dial mechanism 44 of Fig. 6 upon the return traversal of the cutting wheel. As shown previously in Fig. 6, the dial mechanism 44 includes a cogged surface which interacts with pawl 71, thereby maintaining a

count of the number of photographs by means of numbers embossed on the surface of dial mechanism 44. The cutting mechanism 63 is inserted into the platen base 62 by means of a snap fit via clips 74.

The platen unit 60 includes an internal recapping mechanism 80 for recapping the print head when not in use. The recapping mechanism 80 includes a sponge portion 81 and is operated via a solenoid coil so as to provide for recapping of the print head. In the preferred embodiment, there is provided an inexpensive form of printhead re-capping mechanism provided for incorporation into a handheld camera system so as to provide for printhead re-capping of an inkjet printhead.

Fig. 11 illustrates an exploded view of the recapping mechanism whilst Fig. 12 illustrates a close up of the end portion thereof. The re-capping mechanism 80 is structured around a solenoid including a 16 turn coil 75 which can comprise insulated wire. The coil 75 is turned around a first stationery solenoid arm 76 which is mounted on a bottom surface of the platen base 62(Fig. 8) and includes a post portion 77 to magnify effectiveness of operation. The arm 76 can comprise a ferrous material.

A second moveable arm 78 of the solenoid actuator is also provided. The arm 78 is moveable and is also made of ferrous material. Mounted on the arm is a sponge portion surrounded by an elastomer strip 79. The elastomer strip 79 is of a generally arcuate cross-section and act as a leaf spring against the surface of the printhead ink supply cartridge 42 (Fig. 5) so as to provide for a seal against the surface of the printhead ink supply cartridge 42. In the quiescent position an elastomer spring unit 87, 88 acts to resiliently deform the elastomer seal 79 against the surface of the ink supply unit 42.

When it is desired to operate the printhead unit, upon the insertion of paper, the solenoid coil 75 is activated so as to cause the arm 78 to move down to be adjacent to the end plate 76. The arm 78 is held against end plate 76 while the printhead is printing by means of a small "keeper current" in coil 75. Simulation results indicate that the keeper current can be significantly less than the actuation current. Subsequently, after photo printing, the paper is guillotined by the cutting mechanism 63 of Fig. 8 acting against Aluminium Strip 43, and rewound so as to clear the area of the re-capping mechanism 80. Subsequently, the current is turned off and springs 87, 88 return the arm 78 so that the elastomer seal is again resting against the printhead ink supply cartridge.

It can be seen that the preferred embodiment provides for a simple and inexpensive means of re-capping a printhead through the utilisation of a solenoid type device having a long rectangular form. Further, the preferred embodiment utilises minimal power in that currents are only required whilst the device is operational and additionally, only a low keeper current is

required whilst the printhead is printing.

Turning next to Fig. 13 and 14, Fig. 13 illustrates an exploded perspective of the ink supply cartridge 42 whilst Fig. 14 illustrates a close up sectional view of a bottom of the ink supply cartridge with the printhead unit in place. The ink supply cartridge 42 is based around a pagewidth printhead 102 which comprises a long slither of silicon having a series of holes etched on the back surface for the supply of ink to a front surface of the silicon wafer for subsequent ejection via a micro electro mechanical system. The form of ejection can be many different forms such as those set out in the tables below.

Of course, many other inkjet technologies, as referred to the attached tables below, can also be utilised when constructing a printhead unit 102. The fundamental requirement of the ink supply cartridge 42 is the supply of ink to a series of colour channels etched through the back surface of the printhead 102. In the description of the preferred embodiment, it is assumed that a three colour printing process is to be utilised so as to provide full colour picture output. Hence, the print supply unit includes three ink supply reservoirs being a cyan reservoir 104, a magenta reservoir 105 and a yellow reservoir 106. Each of these reservoirs is required to store ink and includes a corresponding sponge type material 107 - 109 which assists in stabilising ink within the corresponding ink channel and inhibiting the ink from sloshing back and forth when the printhead is utilised in a handheld camera system. The reservoirs 104, 105, 106 are formed through the mating of first exterior plastic piece 110 and a second base piece 111.

At a first end 118 of the base piece 111 a series of air inlet 113 – 115 are provided. Each air inlet leads to a corresponding winding channel which is hydrophobically treated so as to act as an ink repellent and therefore repel any ink that may flow along the air inlet channel. The air inlet channel further takes a convoluted path assisting in resisting any ink flow out of the chambers 104 - 106. An adhesive tape portion 117 is provided for sealing the channels within end portion 118.

At the top end, there is included a series of refill holes (not shown) for refilling corresponding ink supply chambers 104, 105, 106. A plug 121 is provided for sealing the refill holes.

Turning now to Fig. 14, there is illustrated a close up perspective view, partly in section through the ink supply cartridge 42 of Fig. 13 when formed as a unit. The ink supply cartridge includes the three colour ink reservoirs 104, 105, 106 which supply ink to different portions of the back surface of printhead 102 which includes a series of apertures 128 defined therein for carriage of the ink to the front surface.

The ink supply cartridge 42 includes two guide walls 124, 125 which separate the various ink chambers and are tapered into an end portion abutting the surface of the printhead

102. The guide walls 124, 125 are further mechanically supported by block portions eg. 126 which are placed at regular intervals along the length of the ink supply unit. The block portions 126 leave space at portions close to the back of printhead 102 for the flow of ink around the back surface thereof.

The ink supply unit is preferably formed from a multi-part plastic injection mould and the mould pieces eg. 110, 111 (Fig. 13) snap together around the sponge pieces 107, 109. Subsequently, a syringe type device can be inserted in the ink refill holes and the ink reservoirs filled with ink with the air flowing out of the air outlets 113 - 115. Subsequently, the adhesive tape portion 117 and plug 121 are attached and the printhead tested for operation capabilities. Subsequently, the ink supply cartridge 42 can be readily removed for refilling by means of removing the ink supply cartridge, performing a washing cycle, and then utilising the holes for the insertion of a refill syringe filled with ink for refilling the ink chamber before returning the ink supply cartridge 42 to a camera.

Turning now to Fig. 15, there is shown an example layout of the Image Capture and Processing ~~Chip~~integrated circuit (ICP) 48.

The Image Capture and Processing ~~Chip~~integrated circuit 48 provides most of the electronic functionality of the camera with the exception of the print head ~~chip~~integrated circuit. The ~~chip~~integrated circuit 48 is a highly integrated system. It combines CMOS image sensing, analog to digital conversion, digital image processing, DRAM storage, ROM, and miscellaneous control functions in a single ~~chip~~integrated circuit.

The ~~chip~~integrated circuit is estimated to be around 32 mm^2 using a leading edge 0.18 micron CMOS/DRAM/APS process. The ~~chip~~integrated circuit size and cost can scale somewhat with Moore's law, but is dominated by a CMOS active pixel sensor array 201, so scaling is limited as the sensor pixels approach the diffraction limit.

The ICP 48 includes CMOS logic, a CMOS image sensor, DRAM, and analog circuitry. A very small amount of flash memory or other non-volatile memory is also preferably included for protection against reverse engineering.

Alternatively, the ICP can readily be divided into two ~~chip~~integrated circuits: one for the CMOS imaging array, and the other for the remaining circuitry. The cost of this two ~~chip~~integrated circuit solution should not be significantly different than the single ~~chip~~integrated circuit ICP, as the extra cost of packaging and bond-pad area is somewhat cancelled by the reduced total wafer area requiring the color filter fabrication steps.

The ICP preferably contains the following functions:

Function

Function
1.5 megapixel image sensor
Analog Signal Processors
Image sensor column decoders
Image sensor row decoders
Analogue to Digital Conversion (ADC)
Column ADC's
Auto exposure
12 Mbits of DRAM
DRAM Address Generator
Color interpolator
Convolver
Color ALU
Halftone matrix ROM
Digital halftoning
Print head interface
8 bit CPU core
Program ROM
Flash memory
Scratchpad SRAM
Parallel interface (8 bit)
Motor drive transistors (5)
Clock PLL
JTAG test interface
Test circuits
Busses
Bond pads

The CPU, DRAM, Image sensor, ROM, Flash memory, Parallel interface, JTAG interface and ADC can be vendor supplied cores. The ICP is intended to run on 1.5V to minimize power consumption and allow convenient operation from two AA type battery cells.

Fig. 15 illustrates a layout of the ICP 48. The ICP 48 is dominated by the imaging array 201, which consumes around 80% of the ~~chip~~integrated circuit area. The imaging array is a CMOS 4 transistor active pixel design with a resolution of 1,500 x 1,000. The array can be divided into the conventional configuration, with two green pixels, one red pixel, and one blue pixel in each pixel group. There are 750 x 500 pixel groups in the imaging array.

The latest advances in the field of image sensing and CMOS image sensing in particular can be found in the October, 1997 issue of IEEE Transactions on Electron Devices and, in particular, pages 1689 to 1968. Further, a specific implementation similar to that disclosed in the present application is disclosed in Wong et. al, "CMOS Active Pixel Image Sensors Fabricated Using a 1.8V, 0.25 μm CMOS Technology", IEDM 1996, page 915

The imaging array uses a 4 transistor active pixel design of a standard configuration. To minimize ~~chip~~integrated circuit area and therefore cost, the image sensor pixels should be as small as feasible with the technology available. With a four transistor cell, the typical pixel size scales as 20 times the lithographic feature size. This allows a minimum pixel area of around 3.6 μm x 3.6 μm. However, the photosite must be substantially above the diffraction limit of the lens. It is also advantageous to have a square photosite, to maximize the margin over the diffraction limit in both horizontal and vertical directions. In this case, the photosite can be specified as 2.5 μm x 2.5 μm. The photosite can be a photogate, pinned photodiode, charge modulation device, or other sensor.

The four transistors are packed as an 'L' shape, rather than a rectangular region, to allow both the pixel and the photosite to be square. This reduces the transistor packing density slightly, increasing pixel size. However, the advantage in avoiding the diffraction limit is greater than the small decrease in packing density.

The transistors also have a gate length which is longer than the minimum for the process technology. These have been increased from a drawn length of 0.18 micron to a drawn length of 0.36 micron. This is to improve the transistor matching by making the variations in gate length represent a smaller proportion of the total gate length.

The extra gate length, and the 'L' shaped packing, mean that the transistors use more area than the minimum for the technology. Normally, around 8 μm^2 would be required for rectangular packing. Preferably, 9.75 μm^2 has been allowed for the transistors.

The total area for each pixel is 16 μm^2, resulting from a pixel size of 4 μm x 4 μm.

With a resolution of 1,500 x 1,000, the area of the imaging array 101 is 6,000 μm x 4,000 μm, or 24 mm^2.

The presence of a color image sensor on the ~~chip~~integrated circuit affects the process required in two major ways:

-The CMOS fabrication process should be optimized to minimize dark current

Color filters are required. These can be fabricated using dyed photosensitive polyimides, resulting in an added process complexity of three spin coatings, three photolithographic steps, three development steps, and three hardbakes.

There are 15,000 analog signal processors (ASPs) 205, one for each of the columns of the sensor. The ASPs amplify the signal, provide a dark current reference, sample and hold the signal, and suppress the fixed pattern noise (FPN).

There are 375 analog to digital converters 206, one for each four columns of the sensor array. These may be delta-sigma or successive approximation type ADC's. A row of low column ADC's are used to reduce the conversion speed required, and the amount of analog signal degradation incurred before the signal is converted to digital. This also eliminates the hot spot (affecting local dark current) and the substrate coupled noise that would occur if a single high speed ADC was used. Each ADC also has two four bit DAC's which trim the offset and scale of the ADC to further reduce FPN variations between columns. These DAC's are controlled by data stored in flash memory during ~~chip~~integrated circuit testing.

The column select logic 204 is a 1:1500 decoder which enables the appropriate digital output of the ADCs onto the output bus. As each ADC is shared by four columns, the least significant two bits of the row select control 4 input analog multiplexors.

A row decoder 207 is a 1:1000 decoder which enables the appropriate row of the active pixel sensor array. This selects which of the 1000 rows of the imaging array is connected to analog signal processors. As the rows are always accessed in sequence, the row select logic can be implemented as a shift register.

An auto exposure system 208 adjusts the reference voltage of the ADC 205 in response to the maximum intensity sensed during the previous frame period. Data from the green pixels is passed through a digital peak detector. The peak value of the image frame period before capture (the reference frame) is provided to a digital to analogue converter(DAC), which generates the global reference voltage for the column ADCs. The peak detector is reset at the beginning of the reference frame. The minimum and maximum values of the three RGB color components are also collected for color correction.

The second largest section of the ~~chip~~integrated circuit is consumed by a DRAM 210 used to hold the image. To store the 1,500 x 1,000 image from the sensor without compression,

1.5 Mbytes of DRAM 210 are required. This equals 12 Mbits, or slightly less than 5% of a 256 Mbit DRAM. The DRAM technology assumed is of the 256 Mbit generation implemented using 0.18μm CMOS.

Using a standard 8F cell, the area taken by the memory array is 3.11 mm^2. When row decoders, column sensors, redundancy, and other factors are taken into account, the DRAM requires around 4 mm^2.

This DRAM 210 can be mostly eliminated if analog storage of the image signal can be accurately maintained in the CMOS imaging array for the two seconds required to print the photo. However, digital storage of the image is preferable as it is maintained without degradation, is insensitive to noise, and allows copies of the photo to be printed considerably later.

A DRAM address generator 211 provides the write and read addresses to the DRAM 210. Under normal operation, the write address is determined by the order of the data read from the CMOS image sensor 201. This will typically be a simple raster format. However, the data can be read from the sensor 201 in any order, if matching write addresses to the DRAM are generated. The read order from the DRAM 210 will normally simply match the requirements of a color interpolator and the print head. As the cyan, magenta, and yellow rows of the print head are necessarily offset by a few pixels to allow space for nozzle actuators, the colors are not read from the DRAM simultaneously. However, there is plenty of time to read all of the data from the DRAM many times during the printing process. This capability is used to eliminate the need for FIFOs in the print head interface, thereby saving ~~chip~~integrated circuit area. All three RGB image components can be read from the DRAM each time color data is required. This allows a color space converter to provide a more sophisticated conversion than a simple linear RGB to CMY conversion.

Also, to allow two dimensional filtering of the image data without requiring line buffers, data is re-read from the DRAM array.

The address generator may also implement image effects in certain models of camera. For example, passport photos are generated by a manipulation of the read addresses to the DRAM. Also, image framing effects (where the central image is reduced), image warps, and kaleidoscopic effects can all be generated by manipulating the read addresses of the DRAM.

While the address generator 211 may be implemented with substantial complexity if effects are built into the standard ~~chip~~integrated circuit, the ~~chip~~integrated circuit area required for the address generator is small, as it consists only of address counters and a moderate amount of random logic.

A color interpolator 214 converts the interleaved pattern of red, 2 x green, and blue

pixels into RGB pixels. It consists of three 8 bit adders and associated registers. The divisions are by either 2 (for green) or 4 (for red and blue) so they can be implemented as fixed shifts in the output connections of the adders.

A convolver 215 is provided as a sharpening filter which applies a small convolution kernel (5 x 5) to the red, green, and blue planes of the image. The convolution kernel for the green plane is different from that of the red and blue planes, as green has twice as many samples. The sharpening filter has five functions:

-To improve the color interpolation from the linear interpolation provided by the color interpolator, to a close approximation of a sinc interpolation.

-To compensate for the image 'softening' which occurs during digitization.

-To adjust the image sharpness to match average consumer preferences, which are typically for the image to be slightly sharper than reality. As the single use camera is intended as a consumer product, and not a professional photographic products, the processing can match the most popular settings, rather than the most accurate.

-To suppress the sharpening of high frequency (individual pixel) noise. The function is similar to the 'unsharp mask' process.

-To antialias Image Warping.

These functions are all combined into a single convolution matrix. As the pixel rate is low (less than 1 Mpixel per second) the total number of multiplies required for the three color channels is 56 million multiplies per second. This can be provided by a single multiplier. Fifty bytes of coefficient ROM are also required.

A color ALU 113 combines the functions of color compensation and color space conversion into the one matrix multiplication, which is applied to every pixel of the frame. As with sharpening, the color correction should match the most popular settings, rather than the most accurate.

A color compensation circuit of the color ALU provides compensation for the lighting of the photo. The vast majority of photographs are substantially improved by a simple color compensation, which independently normalizes the contrast and brightness of the three color components.

A color look-up table (CLUT) 212 is provided for each color component. These are three separate 256 x 8 SRAMs, requiring a total of 6,144 bits. The CLUTs are used as part of the color correction process. They are also used for color special effects, such as stochastically selected "wild color" effects.

A color space conversion system of the color ALU converts from the RGB color space of the image sensor to the CMY color space of the printer. The simplest conversion is a 1's

complement of the RGB data. However, this simple conversion assumes perfect linearity of both color spaces, and perfect dye spectra for both the color filters of the image sensor, and the ink dyes. At the other extreme is a tri-linear interpolation of a sampled three dimensional arbitrary transform table. This can effectively match any non-linearity or differences in either color space. Such a system is usually necessary to obtain good color space conversion when the print engine is a color electrophotographic

However, since the non-linearity of a halftoned ink jet output is very small, a simpler system can be used. A simple matrix multiply can provide excellent results. This requires nine multiplies and six additions per contone pixel. However, since the contone pixel rate is low (less than 1 Mpixel/sec) these operations can share a single multiplier and adder. The multiplier and adder are used in a color ALU which is shared with the color compensation function.

Digital halftoning can be performed as a dispersed dot ordered dither using a stochastic optimized dither cell. A halftone matrix ROM 216 is provided for storing dither cell coefficients. A dither cell size of 32 x 32 is adequate to ensure that the cell repeat cycle is not visible. The three colors – cyan, magenta, and yellow – are all dithered using the same cell, to ensure maximum co-positioning of the ink dots. This minimizes 'muddying' of the mid-tones which results from bleed of dyes from one dot to adjacent dots while still wet. The total ROM size required is 1 KByte, as the one ROM is shared by the halftoning units for each of the three colors.

The digital halftoning used is dispersed dot ordered dither with stochastic optimized dither matrix. While dithering does not produce an image quite as 'sharp' as error diffusion, it does produce a more accurate image with fewer artifacts. The image sharpening produced by error diffusion is artificial, and less controllable and accurate than 'unsharp mask' filtering performed in the contone domain. The high print resolution (1,600 dpi x 1,600 dpi) results in excellent quality when using a well formed stochastic dither matrix.

Digital halftoning is performed by a digital halftoning unit 217 using a simple comparison between the contone information from the DRAM 210 and the contents of the dither matrix 216. During the halftone process, the resolution of the image is changed from the 250 dpi of the captured contone image to the 1,600 dpi of the printed image. Each contone pixel is converted to an average of 40.96 halftone dots.

The ICP incorporates a 16 bit microcontroller CPU core 219 to run the miscellaneous camera functions, such as reading the buttons, controlling the motor and solenoids, setting up the hardware, and authenticating the refill station. The processing power required by the CPU is very modest, and a wide variety of processor cores can be used. As the entire CPU program is run from a small ROM 220[.], program compatibility between camera versions is not important,

as no external programs are run. A 2 Mbit (256 Kbyte) program and data ROM 220 is included on ~~chip~~integrated circuit. Most of this ROM space is allocated to data for outline graphics and fonts for specialty cameras. The program requirements are minor. The single most complex task is the encrypted authentication of the refill station. The ROM requires a single transistor per bit.

A Flash memory 221 may be used to store a 128 bit authentication code. This provides higher security than storage of the authentication code in ROM, as reverse engineering can be made essentially impossible. The Flash memory is completely covered by third level metal, making the data impossible to extract using scanning probe microscopes or electron beams. The authentication code is stored in the ~~chip~~integrated circuit when manufactured. At least two other Flash bits are required for the authentication process: a bit which locks out reprogramming of the authentication code, and a bit which indicates that the camera has been refilled by an authenticated refill station. The flash memory can also be used to store FPN correction data for the imaging array. Additionally, a phase locked loop rescaling parameter is stored for scaling the clocking cycle to an appropriate correct time. The clock frequency does not require crystal accuracy since no date functions are provided. To eliminate the cost of a crystal, an on ~~chip~~integrated circuit oscillator with a phase locked loop 224 is used. As the frequency of an on-~~chip~~integrated circuit oscillator is highly variable from ~~chip~~integrated circuit to ~~chip~~integrated circuit, the frequency ratio of the oscillator to the PLL is digitally trimmed during initial testing. The value is stored in Flash memory 221. This allows the clock PLL to control the ink-jet heater pulse width with sufficient accuracy.

A scratchpad SRAM is a small static RAM 222 with a 6T cell. The scratchpad provided temporary memory for the 16 bit CPU. 1024 bytes is adequate.

A print head interface 223 formats the data correctly for the print head. The print head interface also provides all of the timing signals required by the print head. These timing signals may vary depending upon temperature, the number of dots printed simultaneously, the print medium in the print roll, and the dye density of the ink in the print roll.

The following is a table of external connections to the print head interface:

Connection	Function	Pins
DataBits[0-7]	Independent serial data to the eight segments of the print head	8
BitClock	Main data clock for the print head	1
ColorEnable[0-2]	Independent enable signals for the CMY actuators, allowing different pulse times for each color.	3
BankEnable[0-1]	Allows either simultaneous or interleaved actuation of two banks of nozzles. This allows two different print speed/power consumption tradeoffs	2
NozzleSelect[0-4]	Selects one of 32 banks of nozzles for simultaneous actuation	5
ParallelXferClock	Loads the parallel transfer register with the data from the shift registers	1
Total		20

The print head utilized is composed of eight identical segments, each 1.25 cm long. There is no connection between the segments on the print head ~~chip~~integrated circuit. Any connections required are made in the external TAB bonding film, which is double sided. The division into eight identical segments is to simplify lithography using wafer steppers. The segment width of 1.25 cm fits easily into a stepper field. As the print head ~~chip~~integrated circuit is long and narrow (10 cm x 0.3 mm), the stepper field contains a single segment of 32 print head ~~chip~~integrated circuits. The stepper field is therefore 1.25 cm x 1.6 cm. An average of four complete print heads are patterned in each wafer step.

A single BitClock output line connects to all 8 segments on the print head. The 8 DataBits lines lead one to each segment, and are clocked into the 8 segments on the print head simultaneously (on a BitClock pulse). For example, dot 0 is transferred to $segment_0$, dot 750 is transferred to $segment_1$, dot 1500 to $segment_2$ etc simultaneously.

The ParallelXferClock is connected to each of the 8 segments on the print head, so that on a single pulse, all segments transfer their bits at the same time.

The NozzleSelect, BankEnable and ColorEnable lines are connected to each of the 8 segments, allowing the print head interface to independently control the duration of the cyan, magenta, and yellow nozzle energizing pulses. Registers in the Print Head Interface allow the accurate specification of the pulse duration between 0 and 6 ms, with a typical duration of 2 ms to 3 ms.

A parallel interface 125 connects the ICP to individual static electrical signals. The CPU is able to control each of these connections as memory mapped I/O via a low speed bus.

The following is a table of connections to the parallel interface:

Connection	Direction	Pins
Paper transport stepper motor	Output	4
Capping solenoid	Output	1
Copy LED	Output	1
Photo button	Input	1
Copy button	Input	1
Total		8

Seven high current drive transistors eg. 227 are required. Four are for the four phases of the main stepper motor, two are for the guillotine motor, and the remaining transistor is to drive the capping solenoid. These transistors are allocated 20,000 square microns (600,000 F) each. As the transistors are driving highly inductive loads, they must either be turned off slowly, or be provided with a high level of back EMF protection. If adequate back EMF protection cannot be provided using the ~~chip~~integrated circuit process chosen, then external discrete transistors should be used. The transistors are never driven at the same time as the image sensor is used. This is to avoid voltage fluctuations and hot spots affecting the image quality. Further, the transistors are located as far away from the sensor as possible.

A standard JTAG (Joint Test Action Group) interface 228 is included in the ICP for testing purposes and for interrogation by the refill station. Due to the complexity of the ~~chip~~integrated circuit, a variety of testing techniques are required, including BIST (Built In Self Test) and functional block isolation. An overhead of 10% in ~~chip~~integrated circuit area is assumed for ~~chip~~integrated circuit testing circuitry for the random logic portions. The overhead for the large arrays the image sensor and the DRAM is smaller.

The JTAG interface is also used for authentication of the refill station. This is included to ensure that the cameras are only refilled with quality paper and ink at a properly constructed refill station, thus preventing inferior quality refills from occurring. The camera must authenticate the refill station, rather than vice versa. The secure protocol is communicated to the refill station during the automated test procedure. Contact is made to four gold plated spots on the ICP/print head TAB by the refill station as the new ink is injected into the print head.

Fig. 16 illustrates a rear view of the next step in the construction process whilst Fig. 17 illustrates a front view.

Turning now to Fig. 16, the assembly of the camera system proceeds via first assembling the ink supply mechanism 40. The flex PCB is interconnected with batteries 84 only one of which is shown, which are inserted in the middle portion of a print roll 85 which is wrapped around a plastic former 86. An end cap 89 is provided at the other end of the print roll

85 so as to fasten the print roll and batteries firmly to the ink supply mechanism.

The solenoid coil is interconnected (not shown) to interconnects 97, 98 (Fig. 8) which include leaf spring ends for interconnection with electrical contacts on the Flex PCB so as to provide for electrical control of the solenoid.

Turning now to Figs. 17 - 19 the next step in the construction process is the insertion of the relevant gear trains into the side of the camera chassis. Fig. 17 illustrates a front view, Fig. 18 illustrates a rear view and Fig. 19 also illustrates a rear view. The first gear train comprising gear wheels 22, 23 is utilised for driving the guillotine blade with the gear wheel 23 engaging the gear wheel 65 of Fig. 8. The second gear train comprising gear wheels 24, 25 and 26 engage one end of the print roller 61 of Fig. 8. As best indicated in Fig. 18, the gear wheels mate with corresponding pins on the surface of the chassis with the gear wheel 26 being snap fitted into corresponding mating hole 27.

Next, as illustrated in Fig. 20, the assembled platen unit 60 is then inserted between the print roll 85 and aluminium cutting blade 43.

Turning now to Fig. 21, by way of illumination, there is illustrated the electrically interactive components of the camera system. As noted previously, the components are based around a Flex PCB board and include a TAB film 58 which interconnects the printhead 102 with the image sensor and processing ~~chip~~integrated circuit 48. Power is supplied by two AA type batteries 83, 84 and a paper drive stepper motor 16 is provided in addition to a rotary guillotine motor 17.

An optical element 31 is provided for snapping into a top portion of the chassis 12. The optical element 31 includes portions defining an optical view finder 32, 33 which are slotted into mating portions 35, 36 in view finder channel 37. Also provided in the optical element 31 is a lensing system 38 for magnification of the prints left number in addition to an optical pipe element 39 for piping light from the LED 5 for external display.

Turning next to Fig. 22, the assembled unit 90 is then inserted into a front outer case 91 which includes button 4 for activation of printouts.

Turning now to Fig. 23, next, the unit 90 is provided with a snap-on back cover 93 which includes a slot 6 and copy print button 7. A wrapper label containing instructions and advertising (not shown) is then wrapped around the outer surface of the camera system and pinch clamped to the cover by means of clamp strip 96 which can comprise a flexible plastic or rubber strip.

Subsequently, the preferred embodiment is ready for use as a one time use camera system that provides for instant output images on demand. It will be evident that the preferred embodiment further provides for a refillable camera system. A used camera can be collected and its outer plastic cases removed and recycled. A new paper roll and batteries can be added and the ink cartridge refilled. A series of automatic test routines can then be carried out to ensure that the printer is properly operational. Further, in order to ensure only authorised refills are conducted so as to enhance quality, routines in the on-~~chip~~integrated circuit program ROM can be executed such that the camera authenticates the refilling station using a secure protocol. Upon authentication, the camera can reset an internal paper count and an external case can be fitted on the camera system with a new outer label. Subsequent packing and shipping can then take place.

It will be further readily evident to those skilled in the art that the program ROM can be modified so as to allow for a variety of digital processing routines. In addition to the digitally enhanced photographs optimised for mainstream consumer preferences, various other models can readily be provided through mere re-programming of the program ROM. For example, a

sepia classic old fashion style output can be provided through a remapping of the colour mapping function. A further alternative is to provide for black and white outputs again through a suitable colour remapping algorithm. Minimum colour can also be provided to add a touch of colour to black and white prints to produce the effect that was traditionally used to colourize black and white photos. Further, passport photo output can be provided through suitable address remappings within the address generators. Further, edge filters can be utilised as is known in the field of image processing to produce sketched art styles. Further, classic wedding borders and designs can be placed around an output image in addition to the provision of relevant clip arts. For example, a wedding style camera might be provided. Further, a panoramic mode can be provided so as to output the well known panoramic format of images. Further, a postcard style output can be provided through the printing of postcards including postage on the back of a print roll surface. Further, cliparts can be provided for special events such as Halloween, Christmas etc. Further, kaleidoscopic effects can be provided through address remappings and wild colour effects can be provided through remapping of the colour lookup table. Many other forms of special event cameras can be provided for example, cameras dedicated to the Olympics, movie tie-ins, advertising and other special events.

The operational mode of the camera can be programmed so that upon the depressing of the take photo a first image is sampled by the sensor array to determine irrelevant parameters. Next a second image is again captured which is utilised for the output. The captured image is then manipulated in accordance with any special requirements before being initially output on the paper roll. The LED light is then activated for a predetermined time during which the DRAM is refreshed so as to retain the image. If the print copy button is depressed during this predetermined time interval, a further copy of the photo is output. After the predetermined time interval where no use of the camera has occurred, the onboard CPU shuts down all power to the camera system until such time as the take button is again activated. In this way, substantial power savings can be realized.

Ink Jet Technologies

The embodiments of the invention use an ink jet printer type device. Of course many different devices could be used. However presently popular ink jet printing technologies are unlikely to be suitable.

The most significant problem with thermal inkjet is power consumption. This is approximately 100 times that required for high speed, and stems from the energy-inefficient means of drop ejection. This involves the rapid boiling of water to produce a vapor bubble which expels the ink. Water has a very high heat capacity, and must be superheated in

thermal inkjet applications. This leads to an efficiency of around 0.02%, from electricity input to drop momentum (and increased surface area) out.

The most significant problem with piezoelectric inkjet is size and cost. Piezoelectric crystals have a very small deflection at reasonable drive voltages, and therefore require a large area for each nozzle. Also, each piezoelectric actuator must be connected to its drive circuit on a separate substrate. This is not a significant problem at the current limit of around 300 nozzles per print head, but is a major impediment to the fabrication of pagewide print heads with 19,200 nozzles.

Ideally, the inkjet technologies used meet the stringent requirements of in-camera digital color printing and other high quality, high speed, low cost printing applications. To meet the requirements of digital photography, new inkjet technologies have been created. The target features include:

low power (less than 10 Watts)

high resolution capability (1,600 dpi or more)

photographic quality output

low manufacturing cost

small size (pagewidth times minimum cross section)

high speed (< 2 seconds per page).

All of these features can be met or exceeded by the inkjet systems described below with differing levels of difficulty. 45 different inkjet technologies have been developed by the Assignee to give a wide range of choices for high volume manufacture. These technologies form part of separate applications assigned to the present Assignee as set out in the table below.

The inkjet designs shown here are suitable for a wide range of digital printing systems, from battery powered one-time use digital cameras, through to desktop and network printers, and through to commercial printing systems

For ease of manufacture using standard process equipment, the print head is designed to be a monolithic 0.5 micron CMOS ~~chip~~integrated circuit with MEMS post processing. For color photographic applications, the print head is 100 mm long, with a width which depends upon the inkjet type. The smallest print head designed is IJ38, which is 0.35 mm wide, giving a ~~chip~~integrated circuit area of 35 square mm. The print heads each contain 19,200 nozzles plus data and control circuitry.

Ink is supplied to the back of the print head by injection molded plastic ink channels. The molding requires 50 micron features, which can be created using a lithographically micromachined insert in a standard injection molding tool. Ink flows through holes etched

through the wafer to the nozzle chambers fabricated on the front surface of the wafer. The print head is connected to the camera circuitry by tape automated bonding.

Cross-Referenced Applications

The following table is a guide to cross-referenced patent applications filed concurrently herewith and discussed hereinafter with the reference being utilized in subsequent tables when referring to a particular case:

Docket No.	Reference	Title
IJ01US	IJ01	Radiant Plunger Ink Jet Printer
IJ02US	IJ02	Electrostatic Ink Jet Printer
IJ03US	IJ03	Planar Thermoelastic Bend Actuator Ink Jet
IJ04US	IJ04	Stacked Electrostatic Ink Jet Printer
IJ05US	IJ05	Reverse Spring Lever Ink Jet Printer
IJ06US	IJ06	Paddle Type Ink Jet Printer
IJ07US	IJ07	Permanent Magnet Electromagnetic Ink Jet Printer
IJ08US	IJ08	Planar Swing Grill Electromagnetic Ink Jet Printer
IJ09US	IJ09	Pump Action Refill Ink Jet Printer
IJ10US	IJ10	Pulsed Magnetic Field Ink Jet Printer
IJ11US	IJ11	Two Plate Reverse Firing Electromagnetic Ink Jet Printer
IJ12US	IJ12	Linear Stepper Actuator Ink Jet Printer
IJ13US	IJ13	Gear Driven Shutter Ink Jet Printer
IJ14US	IJ14	Tapered Magnetic Pole Electromagnetic Ink Jet Printer
IJ15US	IJ15	Linear Spring Electromagnetic Grill Ink Jet Printer
IJ16US	IJ16	Lorenz Diaphragm Electromagnetic Ink Jet Printer
IJ17US	IJ17	PTFE Surface Shooting Shuttered Oscillating Pressure Ink Jet Printer
IJ18US	IJ18	Buckle Grip Oscillating Pressure Ink Jet Printer
IJ19US	IJ19	Shutter Based Ink Jet Printer
IJ20US	IJ20	Curling Calyx Thermoelastic Ink Jet Printer
IJ21US	IJ21	Thermal Actuated Ink Jet Printer
IJ22US	IJ22	Iris Motion Ink Jet Printer
IJ23US	IJ23	Direct Firing Thermal Bend Actuator Ink Jet Printer
IJ24US	IJ24	Conductive PTFE Ben Activator Vented Ink Jet Printer
IJ25US	IJ25	Magnetostrictive Ink Jet Printer
IJ26US	IJ26	Shape Memory Alloy Ink Jet Printer
IJ27US	IJ27	Buckle Plate Ink Jet Printer
IJ28US	IJ28	Thermal Elastic Rotary Impeller Ink Jet Printer
IJ29US	IJ29	Thermoelastic Bend Actuator Ink Jet Printer
IJ30US	IJ30	Thermoelastic Bend Actuator Using PTFE and Corrugated Copper Ink Jet Printer
IJ31US	IJ31	Bend Actuator Direct Ink Supply Ink Jet Printer
IJ32US	IJ32	A High Young's Modulus Thermoelastic Ink Jet Printer
IJ33US	IJ33	Thermally actuated slotted chamber wall ink jet printer
IJ34US	IJ34	Ink Jet Printer having a thermal actuator comprising an external coiled spring
IJ35US	IJ35	Trough Container Ink Jet Printer
IJ36US	IJ36	Dual Chamber Single Vertical Actuator Ink Jet
IJ37US	IJ37	Dual Nozzle Single Horizontal Fulcrum Actuator Ink Jet

IJ38US	IJ38	Dual Nozzle Single Horizontal Actuator Ink Jet
IJ39US	IJ39	A single bend actuator cupped paddle ink jet printing device
IJ40US	IJ40	A thermally actuated ink jet printer having a series of thermal actuator units
IJ41US	IJ41	A thermally actuated ink jet printer including a tapered heater element
IJ42US	IJ42	Radial Back-Curling Thermoelastic Ink Jet
IJ43US	IJ43	Inverted Radial Back-Curling Thermoelastic Ink Jet
IJ44US	IJ44	Surface bend actuator vented ink supply ink jet printer
IJ45US	IJ45	Coil Acutuated Magnetic Plate Ink Jet Printer

Tables of Drop-on-Demand Inkjets

Eleven important characteristics of the fundamental operation of individual inkjet nozzles have been identified. These characteristics are largely orthogonal, and so can be elucidated as an eleven dimensional matrix. Most of the eleven axes of this matrix include entries developed by the present assignee.

The following tables form the axes of an eleven dimensional table of inkjet types.

Actuator mechanism (18 types)

Basic operation mode (7 types)

Auxiliary mechanism (8 types)

Actuator amplification or modification method (17 types)

Actuator motion (19 types)

Nozzle refill method (4 types)

Method of restricting back-flow through inlet (10 types)

Nozzle clearing method (9 types)

Nozzle plate construction (9 types)

Drop ejection direction (5 types)

Ink type (7 types)

The complete eleven dimensional table represented by these axes contains 36.9 billion possible configurations of inkjet nozzle. While not all of the possible combinations result in a viable inkjet technology, many million configurations are viable. It is clearly impractical to elucidate all of the possible configurations. Instead, certain inkjet types have been investigated in detail. These are designated IJ01 to IJ45 above.

Other inkjet configurations can readily be derived from these 45 examples by substituting alternative configurations along one or more of the 11 axes. Most of the IJ01 to IJ45 examples can be made into inkjet print heads with characteristics superior to any currently available inkjet technology.

Where there are prior art examples known to the inventor, one or more of these examples are listed in the examples column of the tables below. The IJ01 to IJ45 series are also listed in the examples column. In some cases, a printer may be listed more than once in a table, where it shares characteristics with more than one entry.

Suitable applications include: Home printers, Office network printers, Short run digital printers, Commercial print systems, Fabric printers, Pocket printers, Internet WWW printers, Video printers, Medical imaging, Wide format printers, Notebook PC printers, Fax machines, Industrial printing systems, Photocopiers, Photographic minilabs etc.

The information associated with the aforementioned 11 dimensional matrix are set out in the following tables.

ACTUATOR MECHANISM (APPLIED ONLY TO SELECTED INK DROPS)

Actuator Mechanism	Description	Advantages	Disadvantages	Examples
Thermal bubble	An electrothermal heater heats the ink to above boiling point, transferring significant heat to the aqueous ink. A bubble nucleates and quickly forms, expelling the ink. The efficiency of the process is low, with typically less than 0.05% of the electrical energy being transformed into kinetic energy of the drop.	1) Large force generated 2) Simple construction 3) No moving parts 4) Fast operation 5) Small ~~chip~~integrated circuit area required for actuator	6) High power 7) Ink carrier limited to water 8) Low efficiency 9) High temperatures required 10) High mechanical stress 11) Unusual materials required 12) Large drive transistors 13) Cavitation causes actuator failure 14) Kogation reduces bubble formation 15) Large print heads are difficult to fabricate	16) Canon Bubblejet 1979 Endo et al GB patent 2,007,162 17) Xerox heater-in-pit 1990 Hawkins et al USP 4,899,181 18) Hewlett-Packard TIJ 1982 Vaught et al USP 4,490,728
Piezoelectric	A piezoelectric crystal such as lead lanthanum zirconate (PZT) is electrically activated, and either expands, shears, or bends to apply pressure to the ink, ejecting drops.	19) Low power consumption 20) Many ink types can be used 21) Fast operation 22) High efficiency	23) Very large area required for actuator 24) Difficult to integrate with electronics 25) High voltage drive transistors required 26) Full pagewidth print heads impractical due to actuator size 27) Requires electrical poling in high field strengths during manufacture	28) Kyser et al USP 3,946,398 29) Zoltan USP 3,683,212 30) 1973 Stemme USP 3,747,120 31) Epson Stylus 32) Tektronix 33) IJ04

Electro-strictive	An electric field is used to activate electrostriction in relaxor materials such as lead lanthanum zirconate titanate (PLZT) or lead magnesium niobate (PMN).	34) Low power consumption 35) Many ink types can be used 36) Low thermal expansion 37) Electric field strength required (approx. 3.5 V/µm) can be generated without difficulty 38) Does not require electrical poling	39) Low maximum strain (approx. 0.01%) 40) Large area required for actuator due to low strain 41) Response speed is marginal (~ 10 µs) 42) High voltage drive transistors required 43) Full pagewidth print heads impractical due to actuator size	44) Seiko Epson, Usui et all JP 253401/96 45) IJ04
Ferroelectric	An electric field is used to induce a phase transition between the antiferroelectric (AFE) and ferroelectric (FE) phase. Perovskite materials such as tin modified lead lanthanum zirconate titanate (PLZSnT) exhibit large strains of up to 1% associated with the AFE to FE phase transition.	46) Low power consumption 47) Many ink types can be used 48) Fast operation (< 1 µs) 49) Relatively high longitudinal strain 50) High efficiency 51) Electric field strength of around 3 V/µm can be readily provided	52) Difficult to integrate with electronics 53) Unusual materials such as PLZSnT are required 54) Actuators require a large area	55) IJ04
Electrostatic plates	Conductive plates are separated by a compressible or fluid dielectric (usually air). Upon application of a voltage, the plates attract each other and displace ink, causing drop ejection. The conductive plates may be in a comb or honeycomb structure, or stacked to increase the surface area and therefore the force.	56) Low power consumption 57) Many ink types can be used 58) Fast operation	59) Difficult to operate electrostatic devices in an aqueous environment 60) The electrostatic actuator will normally need to be separated from the ink 61) Very large area required to achieve high forces 62) High voltage drive transistors may be required 63) Full pagewidth print heads are not competitive due to actuator size	64) IJ02, IJ04

Electrostatic pull on ink	A strong electric field is applied to the ink, whereupon electrostatic attraction accelerates the ink towards the print medium.	65) Low current consumption 66) Low temperature	67) High voltage required 68) May be damaged by sparks due to air breakdown 69) Required field strength increases as the drop size decreases 70) High voltage drive transistors required 71) Electrostatic field attracts dust	72) 1989 Saito et al, USP 4,799,068 73) 1989 Miura et al, USP 4,810,954 74) Tone-jet
Permanent magnet electro-magnetic	An electromagnet directly attracts a permanent magnet, displacing ink and causing drop ejection. Rare earth magnets with a field strength around 1 Tesla can be used. Examples are: Samarium Cobalt (SaCo) and magnetic materials in the neodymium iron boron family (NdFeB, NdDyFeBNb, NdDyFeB, etc)	75) Low power consumption 76) Many ink types can be used 77) Fast operation 78) High efficiency 79) Easy extension from single nozzles to pagewidth print heads	80) Complex fabrication 81) Permanent magnetic material such as Neodymium Iron Boron (NdFeB) required. 82) High local currents required 83) Copper metalization should be used for long electromigration lifetime and low resistivity 84) Pigmented inks are usually infeasible 85) Operating temperature limited to the Curie temperature (around 540 K)	86) IJ07, IJ10
Soft magnetic core electro-magnetic	A solenoid induced a magnetic field in a soft magnetic core or yoke fabricated from a ferrous material such as electroplated iron alloys such as CoNiFe [1], CoFe, or NiFe alloys. Typically, the soft magnetic material is in two parts, which are normally held apart by a spring. When the solenoid is actuated, the two parts attract, displacing the ink.	87) Low power consumption 88) Many ink types can be used 89) Fast operation 90) High efficiency 91) Easy extension from single nozzles to pagewidth print heads	92) Complex fabrication 93) Materials not usually present in a CMOS fab such as NiFe, CoNiFe, or CoFe are required 94) High local currents required 95) Copper metalization should be used for long electromigration lifetime and low resistivity 96) Electroplating is required 97) High saturation flux density is required (2.0-2.1 T is achievable with CoNiFe [1])	98) IJ01, IJ05, IJ08, IJ10 99) IJ12, IJ14, IJ15, IJ17

Magnetic Lorenz force	The Lorenz force acting on a current carrying wire in a magnetic field is utilized. This allows the magnetic field to be supplied externally to the print head, for example with rare earth permanent magnets. Only the current carrying wire need be fabricated on the print-head, simplifying materials requirements.	100) Low power consumption 101) Many ink types can be used 102) Fast operation 103) High efficiency 104) Easy extension from single nozzles to pagewidth print heads	105) Force acts as a twisting motion 106) Typically, only a quarter of the solenoid length provides force in a useful direction 107) High local currents required 108) Copper metalization should be used for long electromigration lifetime and low resistivity 109) Pigmented inks are usually infeasible	110) IJ06, IJ11, IJ13, IJ16
Magneto-striction	The actuator uses the giant magnetostrictive effect of materials such as Terfenol-D (an alloy of terbium, dysprosium and iron developed at the Naval Ordnance Laboratory, hence Ter-Fe-NOL). For best efficiency, the actuator should be pre-stressed to approx. 8 MPa.	111) Many ink types can be used 112) Fast operation 113) Easy extension from single nozzles to pagewidth print heads 114) High force is available	115) Force acts as a twisting motion 116) Unusual materials such as Terfenol-D are required 117) High local currents required 118) Copper metalization should be used for long electromigration lifetime and low resistivity 119) Pre-stressing may be required	120) Fischenbeck, USP 4,032,929 121) IJ25
Surface tension reduction	Ink under positive pressure is held in a nozzle by surface tension. The surface tension of the ink is reduced below the bubble threshold, causing the ink to egress from the nozzle.	122) Low power consumption 123) Simple construction 124) No unusual materials required in fabrication 125) High efficiency 126) Easy extension from single nozzles to pagewidth print heads	127) Requires supplementary force to effect drop separation 128) Requires special ink surfactants 129) Speed may be limited by surfactant properties	130) Silverbrook, EP 0771 658 A2 and related patent applications

Viscosity reduction	The ink viscosity is locally reduced to select which drops are to be ejected. A viscosity reduction can be achieved electrothermally with most inks, but special inks can be engineered for a 100:1 viscosity reduction.	131) Simple construction 132) No unusual materials required in fabrication 133) Easy extension from single nozzles to pagewidth print heads	134) Requires supplementary force to effect drop separation 135) Requires special ink viscosity properties 136) High speed is difficult to achieve 137) Requires oscillating ink pressure 138) A high temperature difference (typically 80 degrees) is required	139) Silverbrook, EP 0771 658 A2 and related patent applications
Acoustic	An acoustic wave is generated and focussed upon the drop ejection region.	140) Can operate without a nozzle plate	141) Complex drive circuitry 142) Complex fabrication 143) Low efficiency 144) Poor control of drop position 145) Poor control of drop volume	146) 1993 Hadimioglu et al, EUP 550,192 147) 1993 Elrod et al, EUP 572,220
Thermoelastic bend actuator	An actuator which relies upon differential thermal expansion upon Joule heating is used.	148) Low power consumption 149) Many ink types can be used 150) Simple planar fabrication 151) Small ~~chip~~integrated circuit area required for each actuator 152) Fast operation 153) High efficiency 154) CMOS compatible voltages and currents 155) Standard MEMS processes can be used 156) Easy extension from single nozzles to pagewidth print heads	157) Efficient aqueous operation requires a thermal insulator on the hot side 158) Corrosion prevention can be difficult 159) Pigmented inks may be infeasible, as pigment particles may jam the bend actuator	160) IJ03, IJ09, IJ17, IJ18 161) IJ19, IJ20, IJ21, IJ22 162) IJ23, IJ24, IJ27, IJ28 163) IJ29, IJ30, IJ31, IJ32 164) IJ33, IJ34, IJ35, IJ36 165) IJ37, IJ38 ,IJ39, IJ40 166) IJ41

High CTE thermoelastic actuator	A material with a very high coefficient of thermal expansion (CTE) such as polytetrafluoroethylene (PTFE) is used. As high CTE materials are usually non-conductive, a heater fabricated from a conductive material is incorporated. A 50 µm long PTFE bend actuator with polysilicon heater and 15 mW power input can provide 180 µN force and 10 µm deflection. Actuator motions include: Bend Push Buckle Rotate	167) High force can be generated 168) PTFE is a candidate for low dielectric constant insulation in ULSI 169) Very low power consumption 170) Many ink types can be used 171) Simple planar fabrication 172) Small ~~chip~~integrated circuit area required for each actuator 173) Fast operation 174) High efficiency 175) CMOS compatible voltages and currents 176) Easy extension from single nozzles to pagewidth print heads	177) Requires special material (e.g. PTFE) 178) Requires a PTFE deposition process, which is not yet standard in ULSI fabs 179) PTFE deposition cannot be followed with high temperature (above 350 °C) processing 180) Pigmented inks may be infeasible, as pigment particles may jam the bend actuator	181) IJ09, IJ17, IJ18, IJ20 182) IJ21, IJ22, IJ23, IJ24 183) IJ27, IJ28, IJ29, IJ30 184) IJ31, IJ42, IJ43, IJ44

Conductive polymer thermoelastic actuator	A polymer with a high coefficient of thermal expansion (such as PTFE) is doped with conducting substances to increase its conductivity to about 3 orders of magnitude below that of copper. The conducting polymer expands when resistively heated. Examples of conducting dopants include: Carbon nanotubes Metal fibers Conductive polymers such as doped polythiophene Carbon granules	185) High force can be generated 186) Very low power consumption 187) Many ink types can be used 188) Simple planar fabrication 189) Small ~~chip~~integrated circuit area required for each actuator 190) Fast operation 191) High efficiency 192) CMOS compatible voltages and currents 193) Easy extension from single nozzles to pagewidth print heads	194) Requires special materials development (High CTE conductive polymer) 195) Requires a PTFE deposition process, which is not yet standard in ULSI fabs 196) PTFE deposition cannot be followed with high temperature (above 350 °C) processing 197) Evaporation and CVD deposition techniques cannot be used 198) Pigmented inks may be infeasible, as pigment particles may jam the bend actuator	199) IJ24
Shape memory alloy	A shape memory alloy such as TiNi (also known as Nitinol - Nickel Titanium alloy developed at the Naval Ordnance Laboratory) is thermally switched between its weak martensitic state and its high stiffness austenic state. The shape of the actuator in its martensitic state is deformed relative to the austenic shape. The shape change causes ejection of a drop.	200) High force is available (stresses of hundreds of MPa) 201) Large strain is available (more than 3%) 202) High corrosion resistance 203) Simple construction 204) Easy extension from single nozzles to pagewidth print heads 205) Low voltage operation	206) Fatigue limits maximum number of cycles 207) Low strain (1%) is required to extend fatigue resistance 208) Cycle rate limited by heat removal 209) Requires unusual materials (TiNi) 210) The latent heat of transformation must be provided 211) High current operation 212) Requires pre-stressing to distort the martensitic state	213) IJ26

Linear Magnetic Actuator	Linear magnetic actuators include the Linear Induction Actuator (LIA), Linear Permanent Magnet Synchronous Actuator (LPMSA), Linear Reluctance Synchronous Actuator (LRSA), Linear Switched Reluctance Actuator (LSRA), and the Linear Stepper Actuator (LSA).	214) Linear Magnetic actuators can be constructed with high thrust, long travel, and high efficiency using planar semiconductor fabrication techniques 215) Long actuator travel is available 216) Medium force is available 217) Low voltage operation	218) Requires unusual semiconductor materials such as soft magnetic alloys (e.g. CoNiFe [1]) 219) Some varieties also require permanent magnetic materials such as Neodymium iron boron (NdFeB) 220) Requires complex multi-phase drive circuitry 221) High current operation	222) IJ12

BASIC OPERATION MODE

Operational mode	Description	Advantages	Disadvantages	Examples
Actuator directly pushes ink	This is the simplest mode of operation: the actuator directly supplies sufficient kinetic energy to expel the drop. The drop must have a sufficient velocity to overcome the surface tension.	223) Simple operation 224) No external fields required 225) Satellite drops can be avoided if drop velocity is less than 4 m/s 226) Can be efficient, depending upon the actuator used	227) Drop repetition rate is usually limited to less than 10 KHz. However, this is not fundamental to the method, but is related to the refill method normally used 228) All of the drop kinetic energy must be provided by the actuator 229) Satellite drops usually form if drop velocity is greater than 4.5 m/s	230) Thermal inkjet 231) Piezoelectric inkjet 232) IJ01, IJ02, IJ03, IJ04 233) IJ05, IJ06, IJ07, IJ09 234) IJ11, IJ12, IJ14, IJ16 235) IJ20, IJ22, IJ23, IJ24 236) IJ25, IJ26, IJ27, IJ28 237) IJ29, IJ30, IJ31, IJ32 238) IJ33, IJ34, IJ35, IJ36 239) IJ37, IJ38, IJ39, IJ40 240) IJ41, IJ42, IJ43, IJ44
Proximity	The drops to be printed are selected by some manner (e.g. thermally induced surface tension reduction of pressurized ink). Selected drops are separated from the ink in the nozzle by contact with the print medium or a transfer roller.	241) Very simple print head fabrication can be used 242) The drop selection means does not need to provide the energy required to separate the drop from the nozzle	243) Requires close proximity between the print head and the print media or transfer roller 244) May require two print heads printing alternate rows of the image 245) Monolithic color print heads are difficult	246) Silverbrook, EP 0771 658 A2 and related patent applications

Electrostatic pull on ink	The drops to be printed are selected by some manner (e.g. thermally induced surface tension reduction of pressurized ink). Selected drops are separated from the ink in the nozzle by a strong electric field.	247) Very simple print head fabrication can be used 248) The drop selection means does not need to provide the energy required to separate the drop from the nozzle	249) Requires very high electrostatic field 250) Electrostatic field for small nozzle sizes is above air breakdown 251) Electrostatic field may attract dust	252) Silverbrook, EP 0771 658 A2 and related patent applications 253) Tone-Jet
Magnetic pull on ink	The drops to be printed are selected by some manner (e.g. thermally induced surface tension reduction of pressurized ink). Selected drops are separated from the ink in the nozzle by a strong magnetic field acting on the magnetic ink.	254) Very simple print head fabrication can be used 255) The drop selection means does not need to provide the energy required to separate the drop from the nozzle	256) Requires magnetic ink 257) Ink colors other than black are difficult 258) Requires very high magnetic fields	259) Silverbrook, EP 0771 658 A2 and related patent applications
Shutter	The actuator moves a shutter to block ink flow to the nozzle. The ink pressure is pulsed at a multiple of the drop ejection frequency.	260) High speed (>50 KHz) operation can be achieved due to reduced refill time 261) Drop timing can be very accurate 262) The actuator energy can be very low	263) Moving parts are required 264) Requires ink pressure modulator 265) Friction and wear must be considered 266) Stiction is possible	267) IJ13, IJ17, IJ21
Shuttered grill	The actuator moves a shutter to block ink flow through a grill to the nozzle. The shutter movement need only be equal to the width of the grill holes.	268) Actuators with small travel can be used 269) Actuators with small force can be used 270) High speed (>50 KHz) operation can be achieved	271) Moving parts are required 272) Requires ink pressure modulator 273) Friction and wear must be considered 274) Stiction is possible	275) IJ08, IJ15, IJ18, IJ19
Pulsed magnetic pull on ink pusher	A pulsed magnetic field attracts an 'ink pusher' at the drop ejection frequency. An actuator controls a catch, which prevents the ink pusher from moving when a drop is not to be ejected.	276) Extremely low energy operation is possible 277) No heat dissipation problems	278) Requires an external pulsed magnetic field 279) Requires special materials for both the actuator and the ink pusher 280) Complex construction	281) IJ10

AUXILIARY MECHANISM (APPLIED TO ALL NOZZLES)

Auxiliary Mechanism	Description	Advantages	Disadvantages	Examples
None	The actuator directly fires the ink drop, and there is no external field or other mechanism required.	282) Simplicity of construction 283) Simplicity of operation 284) Small physical size	285) Drop ejection energy must be supplied by individual nozzle actuator	286) Most inkjets, including piezoelectric and thermal bubble. 287) IJ01- IJ07, IJ09, IJ11 288) IJ12, IJ14, IJ20, IJ22 289) IJ23-IJ45
Oscillating ink pressure (including acoustic stimulation)	The ink pressure oscillates, providing much of the drop ejection energy. The actuator selects which drops are to be fired by selectively blocking or enabling nozzles. The ink pressure oscillation may be achieved by vibrating the print head, or preferably by an actuator in the ink supply.	290) Oscillating ink pressure can provide a refill pulse, allowing higher operating speed 291) The actuators may operate with much lower energy 292) Acoustic lenses can be used to focus the sound on the nozzles	293) Requires external ink pressure oscillator 294) Ink pressure phase and amplitude must be carefully controlled 295) Acoustic reflections in the ink chamber must be designed for	296) Silverbrook, EP 0771 658 A2 and related patent applications 297) IJ08, IJ13, IJ15, IJ17 298) IJ18, IJ19, IJ21
Media proximity	The print head is placed in close proximity to the print medium. Selected drops protrude from the print head further than unselected drops, and contact the print medium. The drop soaks into the medium fast enough to cause drop separation.	299) Low power 300) High accuracy 301) Simple print head construction	302) Precision assembly required 303) Paper fibers may cause problems 304) Cannot print on rough substrates	305) Silverbrook, EP 0771 658 A2 and related patent applications

Transfer roller	Drops are printed to a transfer roller instead of straight to the print medium. A transfer roller can also be used for proximity drop separation.	306) High accuracy 307) Wide range of print substrates can be used 308) Ink can be dried on the transfer roller	309) Bulky 310) Expensive 311) Complex construction	312) Silverbrook, EP 0771 658 A2 and related patent applications 313) Tektronix hot melt piezoelectric inkjet 314) Any of the IJ series
Electrostatic	An electric field is used to accelerate selected drops towards the print medium.	315) Low power 316) Simple print head construction	317) Field strength required for separation of small drops is near or above air breakdown	318) Silverbrook, EP 0771 658 A2 and related patent applications 319) Tone-Jet
Direct magnetic field	A magnetic field is used to accelerate selected drops of magnetic ink towards the print medium.	320) Low power 321) Simple print head construction	322) Requires magnetic ink 323) Requires strong magnetic field	324) Silverbrook, EP 0771 658 A2 and related patent applications
Cross magnetic field	The print head is placed in a constant magnetic field. The Lorenz force in a current carrying wire is used to move the actuator.	325) Does not require magnetic materials to be integrated in the print head manufacturing process	326) Requires external magnet 327) Current densities may be high, resulting in electromigration problems	328) IJ06, IJ16
Pulsed magnetic field	A pulsed magnetic field is used to cyclically attract a paddle, which pushes on the ink. A small actuator moves a catch, which selectively prevents the paddle from moving.	329) Very low power operation is possible 330) Small print head size	331) Complex print head construction 332) Magnetic materials required in print head	333) IJ10

ACTUATOR AMPLIFICATION OR MODIFICATION METHOD

Actuator amplification	Description	Advantages	Disadvantages	Examples
None	No actuator mechanical amplification is used. The actuator directly drives the drop ejection process.	334) Operational simplicity	335) Many actuator mechanisms have insufficient travel, or insufficient force, to efficiently drive the drop ejection process	336) Thermal Bubble Inkjet 337) IJ01, IJ02, IJ06, IJ07 338) IJ16, IJ25, IJ26
Differential expansion bend actuator	An actuator material expands more on one side than on the other. The expansion may be thermal, piezoelectric, magnetostrictive, or other mechanism.	339) Provides greater travel in a reduced print head area 340) The bend actuator converts a high force low travel actuator mechanism to high travel, lower force mechanism.	341) High stresses are involved 342) Care must be taken that the materials do not delaminate 343) Residual bend resulting from high temperature or high stress during formation	344) Piezoelectric 345) IJ03, IJ09, IJ17-IJ24 346) IJ27, IJ29-IJ39, IJ42, 347) IJ43, IJ44
Transient bend actuator	A trilayer bend actuator where the two outside layers are identical. This cancels bend due to ambient temperature and residual stress. The actuator only responds to transient heating of one side or the other.	348) Very good temperature stability 349) High speed, as a new drop can be fired before heat dissipates 350) Cancels residual stress of formation	351) High stresses are involved 352) Care must be taken that the materials do not delaminate	353) IJ40, IJ41
Actuator stack	A series of thin actuators are stacked. This can be appropriate where actuators require high electric field strength, such as electrostatic and piezoelectric actuators.	354) Increased travel 355) Reduced drive voltage	356) Increased fabrication complexity 357) Increased possibility of short circuits due to pinholes	358) Some piezoelectric ink jets 359) IJ04
Multiple actuators	Multiple smaller actuators are used simultaneously to move the ink. Each actuator need provide only a portion of the force required.	360) Increases the force available from an actuator 361) Multiple actuators can be positioned to control ink flow accurately	362) Actuator forces may not add linearly, reducing efficiency	363) IJ12, IJ13, IJ18, IJ20 364) IJ22, IJ28, IJ42, IJ43

Linear Spring	A linear spring is used to transform a motion with small travel and high force into a longer travel, lower force motion.	365) Matches low travel actuator with higher travel requirements 366) Non-contact method of motion transformation	367) Requires print head area for the spring	368) IJ15
Reverse spring	The actuator loads a spring. When the actuator is turned off, the spring releases. This can reverse the force/distance curve of the actuator to make it compatible with the force/time requirements of the drop ejection.	369) Better coupling to the ink	370) Fabrication complexity 371) High stress in the spring	372) IJ05, IJ11
Coiled actuator	A bend actuator is coiled to provide greater travel in a reduced ~~chip~~integrated circuit area.	373) Increases travel 374) Reduces ~~chip~~integrated circuit area 375) Planar implementations are relatively easy to fabricate.	376) Generally restricted to planar implementations due to extreme fabrication difficulty in other orientations.	377) IJ17, IJ21, IJ34, IJ35
Flexure bend actuator	A bend actuator has a small region near the fixture point, which flexes much more readily than the remainder of the actuator. The actuator flexing is effectively converted from an even coiling to an angular bend, resulting in greater travel of the actuator tip.	378) Simple means of increasing travel of a bend actuator	379) Care must be taken not to exceed the elastic limit in the flexure area 380) Stress distribution is very uneven 381) Difficult to accurately model with finite element analysis	382) IJ10, IJ19, IJ33
Gears	Gears can be used to increase travel at the expense of duration. Circular gears, rack and pinion, ratchets, and other gearing methods can be used.	383) Low force, low travel actuators can be used 384) Can be fabricated using standard surface MEMS processes	385) Moving parts are required 386) Several actuator cycles are required 387) More complex drive electronics 388) Complex construction 389) Friction, friction, and wear are possible	390) IJ13

Catch	The actuator controls a small catch. The catch either enables or disables movement of an ink pusher that is controlled in a bulk manner.	391) Very low actuator energy 392) Very small actuator size	393) Complex construction 394) Requires external force 395) Unsuitable for pigmented inks	396) IJ10
Buckle plate	A buckle plate can be used to change a slow actuator into a fast motion. It can also convert a high force, low travel actuator into a high travel, medium force motion.	397) Very fast movement achievable	398) Must stay within elastic limits of the materials for long device life 399) High stresses involved 400) Generally high power requirement	401) S. Hirata et al, "An Ink-jet Head ...", Proc. IEEE MEMS, Feb. 1996, pp 418-423. 402) IJ18, IJ27
Tapered magnetic pole	A tapered magnetic pole can increase travel at the expense of force.	403) Linearizes the magnetic force/distance curve	404) Complex construction	405) IJ14
Lever	A lever and fulcrum is used to transform a motion with small travel and high force into a motion with longer travel and lower force. The lever can also reverse the direction of travel.	406) Matches low travel actuator with higher travel requirements 407) Fulcrum area has no linear movement, and can be used for a fluid seal	408) High stress around the fulcrum	409) IJ32, IJ36, IJ37
Rotary impeller	The actuator is connected to a rotary impeller. A small angular deflection of the actuator results in a rotation of the impeller vanes, which push the ink against stationary vanes and out of the nozzle.	410) High mechanical advantage 411) The ratio of force to travel of the actuator can be matched to the nozzle requirements by varying the number of impeller vanes	412) Complex construction 413) Unsuitable for pigmented inks	414) IJ28
Acoustic lens	A refractive or diffractive (e.g. zone plate) acoustic lens is used to concentrate sound waves.	415) No moving parts	416) Large area required 417) Only relevant for acoustic ink jets	418) 1993 Hadimioglu et al, EUP 550,192 419) 1993 Elrod et al, EUP 572,220

Sharp conductive point	A sharp point is used to concentrate an electrostatic field.	420) Simple construction	421) Difficult to fabricate using standard VLSI processes for a surface ejecting ink-jet 422) Only relevant for electrostatic ink jets	423) Tone-jet

ACTUATOR MOTION

Actuator motion	Description	Advantages	Disadvantages	Examples
Volume expansion	The volume of the actuator changes, pushing the ink in all directions.	424) Simple construction in the case of thermal ink jet	425) High energy is typically required to achieve volume expansion. This leads to thermal stress, cavitation, and kogation in thermal ink jet implementations	426) Hewlett-Packard Thermal Inkjet 427) Canon Bubblejet
Linear, normal to ~~chip~~integrated circuit surface	The actuator moves in a direction normal to the print head surface. The nozzle is typically in the line of movement.	428) Efficient coupling to ink drops ejected normal to the surface	429) High fabrication complexity may be required to achieve perpendicular motion	430) IJ01, IJ02, IJ04, IJ07 431) IJ11, IJ14
Linear, parallel to ~~chip~~integrated circuit surface	The actuator moves parallel to the print head surface. Drop ejection may still be normal to the surface.	432) Suitable for planar fabrication	433) Fabrication complexity 434) Friction 435) Stiction	436) IJ12, IJ13, IJ15, IJ33, 437) IJ34, IJ35, IJ36
Membrane push	An actuator with a high force but small area is used to push a stiff membrane that is in contact with the ink.	438) The effective area of the actuator becomes the membrane area	439) Fabrication complexity 440) Actuator size 441) Difficulty of integration in a VLSI process	442) 1982 Howkins USP 4,459,601
Rotary	The actuator causes the rotation of some element, such a grill or impeller	443) Rotary levers may be used to increase travel 444) Small ~~chip~~integrated circuit area requirements	445) Device complexity 446) May have friction at a pivot point	447) IJ05, IJ08, IJ13, IJ28

Bend	The actuator bends when energized. This may be due to differential thermal expansion, piezoelectric expansion, magnetostriction, or other form of relative dimensional change.	448) A very small change in dimensions can be converted to a large motion.	449) Requires the actuator to be made from at least two distinct layers, or to have a thermal difference across the actuator	450) 1970 Kyser et al USP 3,946,398 451) 1973 Stemme USP 3,747,120 452) IJ03, IJ09, IJ10, IJ19 453) IJ23, IJ24, IJ25, IJ29 454) IJ30, IJ31, IJ33, IJ34 455) IJ35
Swivel	The actuator swivels around a central pivot. This motion is suitable where there are opposite forces applied to opposite sides of the paddle, e.g. Lorenz force.	456) Allows operation where the net linear force on the paddle is zero 457) Small ~~chip~~integrated circuit area requirements	458) Inefficient coupling to the ink motion	459) IJ06
Straighten	The actuator is normally bent, and straightens when energized.	460) Can be used with shape memory alloys where the austenic phase is planar	461) Requires careful balance of stresses to ensure that the quiescent bend is accurate	462) IJ26, IJ32
Double bend	The actuator bends in one direction when one element is energized, and bends the other way when another element is energized.	463) One actuator can be used to power two nozzles. 464) Reduced ~~chip~~integrated circuit size. 465) Not sensitive to ambient temperature	466) Difficult to make the drops ejected by both bend directions identical. 467) A small efficiency loss compared to equivalent single bend actuators.	468) IJ36, IJ37, IJ38
Shear	Energizing the actuator causes a shear motion in the actuator material.	469) Can increase the effective travel of piezoelectric actuators	470) Not readily applicable to other actuator mechanisms	471) 1985 Fishbeck USP 4,584,590
Radial constriction	The actuator squeezes an ink reservoir, forcing ink from a constricted nozzle.	472) Relatively easy to fabricate single nozzles from glass tubing as macroscopic structures	473) High force required 474) Inefficient 475) Difficult to integrate with VLSI processes	476) 1970 Zoltan USP 3,683,212

Coil / uncoil	A coiled actuator uncoils or coils more tightly. The motion of the free end of the actuator ejects the ink.	477) Easy to fabricate as a planar VLSI process 478) Small area required, therefore low cost	479) Difficult to fabricate for non-planar devices 480) Poor out-of-plane stiffness	481) IJ17, IJ21, IJ34, IJ35
Bow	The actuator bows (or buckles) in the middle when energized.	482) Can increase the speed of travel 483) Mechanically rigid	484) Maximum travel is constrained 485) High force required	486) IJ16, IJ18, IJ27
Push-Pull	Two actuators control a shutter. One actuator pulls the shutter, and the other pushes it.	487) The structure is pinned at both ends, so has a high out-of-plane rigidity	488) Not readily suitable for inkjets which directly push the ink	489) IJ18
Curl inwards	A set of actuators curl inwards to reduce the volume of ink that they enclose.	490) Good fluid flow to the region behind the actuator increases efficiency	491) Design complexity	492) IJ20, IJ42
Curl outwards	A set of actuators curl outwards, pressurizing ink in a chamber surrounding the actuators, and expelling ink from a nozzle in the chamber.	493) Relatively simple construction	494) Relatively large ~~chip~~integrated circuit area	495) IJ43
Iris	Multiple vanes enclose a volume of ink. These simultaneously rotate, reducing the volume between the vanes.	496) High efficiency 497) Small ~~chip~~integrated circuit area	498) High fabrication complexity 499) Not suitable for pigmented inks	500) IJ22
Acoustic vibration	The actuator vibrates at a high frequency.	501) The actuator can be physically distant from the ink	502) Large area required for efficient operation at useful frequencies 503) Acoustic coupling and crosstalk 504) Complex drive circuitry 505) Poor control of drop volume and position	506) 1993 Hadimioglu et al, EUP 550,192 507) 1993 Elrod et al, EUP 572,220
None	In various ink jet designs the actuator does not move.	508) No moving parts	509) Various other tradeoffs are required to eliminate moving parts	510) Silverbrook, EP 0771 658 A2 and related patent applications 511) Tone-jet

NOZZLE REFILL METHOD

Nozzle refill method	Description	Advantages	Disadvantages	Examples
Surface tension	After the actuator is energized, it typically returns rapidly to its normal position. This rapid return sucks in air through the nozzle opening. The ink surface tension at the nozzle then exerts a small force restoring the meniscus to a minimum area.	512) Fabrication simplicity 513) Operational simplicity	514) Low speed 515) Surface tension force relatively small compared to actuator force 516) Long refill time usually dominates the total repetition rate	517) Thermal inkjet 518) Piezoelectric inkjet 519) IJ01-IJ07, IJ10-IJ14 520) IJ16, IJ20, IJ22-IJ45
Shuttered oscillating ink pressure	Ink to the nozzle chamber is provided at a pressure that oscillates at twice the drop ejection frequency. When a drop is to be ejected, the shutter is opened for 3 half cycles: drop ejection, actuator return, and refill.	521) High speed 522) Low actuator energy, as the actuator need only open or close the shutter, instead of ejecting the ink drop	523) Requires common ink pressure oscillator 524) May not be suitable for pigmented inks	525) IJ08, IJ13, IJ15, IJ17 526) IJ18, IJ19, IJ21
Refill actuator	After the main actuator has ejected a drop a second (refill) actuator is energized. The refill actuator pushes ink into the nozzle chamber. The refill actuator returns slowly, to prevent its return from emptying the chamber again.	527) High speed, as the nozzle is actively refilled	528) Requires two independent actuators per nozzle	529) IJ09
Positive ink pressure	The ink is held a slight positive pressure. After the ink drop is ejected, the nozzle chamber fills quickly as surface tension and ink pressure both operate to refill the nozzle.	530) High refill rate, therefore a high drop repetition rate is possible	531) Surface spill must be prevented 532) Highly hydrophobic print head surfaces are required	533) Silverbrook, EP 0771 658 A2 and related patent applications 534) Alternative for: 535) IJ01-IJ07, IJ10-IJ14 536) IJ16, IJ20, IJ22-IJ45

METHOD OF RESTRICTING BACK-FLOW THROUGH INLET

Inlet back-flow restriction method	Description	Advantages	Disadvantages	Examples
Long inlet channel	The ink inlet channel to the nozzle chamber is made long and relatively narrow, relying on viscous drag to reduce inlet back-flow.	537) Design simplicity 538) Operational simplicity 539) Reduces crosstalk	540) Restricts refill rate 541) May result in a relatively large ~~chip~~integrated circuit area 542) Only partially effective	543) Thermal inkjet 544) Piezoelectric inkjet 545) IJ42, IJ43
Positive ink pressure	The ink is under a positive pressure, so that in the quiescent state some of the ink drop already protrudes from the nozzle. This reduces the pressure in the nozzle chamber which is required to eject a certain volume of ink. The reduction in chamber pressure results in a reduction in ink pushed out through the inlet.	546) Drop selection and separation forces can be reduced 547) Fast refill time	548) Requires a method (such as a nozzle rim or effective hydrophobizing, or both) to prevent flooding of the ejection surface of the print head.	549) Silverbrook, EP 0771 658 A2 and related patent applications 550) Possible operation of the following: 551) IJ01-IJ07, IJ09-IJ12 552) IJ14, IJ16, IJ20, IJ22, 553) IJ23-IJ34, IJ36-IJ41 554) IJ44
Baffle	One or more baffles are placed in the inlet ink flow. When the actuator is energized, the rapid ink movement creates eddies which restrict the flow through the inlet. The slower refill process is unrestricted, and does not result in eddies.	555) The refill rate is not as restricted as the long inlet method. 556) Reduces crosstalk	557) Design complexity 558) May increase fabrication complexity (e.g. Tektronix hot melt Piezoelectric print heads).	559) HP Thermal Ink Jet 560) Tektronix piezoelectric ink jet

Flexible flap restricts inlet	In this method recently disclosed by Canon, the expanding actuator (bubble) pushes on a flexible flap that restricts the inlet.	561) Significantly reduces back-flow for edge-shooter thermal ink jet devices	562) Not applicable to most inkjet configurations 563) Increased fabrication complexity 564) Inelastic deformation of polymer flap results in creep over extended use	565) Canon
Inlet filter	A filter is located between the ink inlet and the nozzle chamber. The filter has a multitude of small holes or slots, restricting ink flow. The filter also removes particles which may block the nozzle.	566) Additional advantage of ink filtration 567) Ink filter may be fabricated with no additional process steps	568) Restricts refill rate 569) May result in complex construction	570) IJ04, IJ12, IJ24, IJ27 571) IJ29, IJ30
Small inlet compared to nozzle	The ink inlet channel to the nozzle chamber has a substantially smaller cross section than that of the nozzle , resulting in easier ink egress out of the nozzle than out of the inlet.	572) Design simplicity	573) Restricts refill rate 574) May result in a relatively large ~~chip~~integrated circuit area 575) Only partially effective	576) IJ02, IJ37, IJ44
Inlet shutter	A secondary actuator controls the position of a shutter, closing off the ink inlet when the main actuator is energized.	577) Increases speed of the ink-jet print head operation	578) Requires separate refill actuator and drive circuit	579) IJ09
The inlet is located behind the ink-pushing surface	The method avoids the problem of inlet back-flow by arranging the ink-pushing surface of the actuator between the inlet and the nozzle.	580) Back-flow problem is eliminated	581) Requires careful design to minimize the negative pressure behind the paddle	582) IJ01, IJ03, 1J05, IJ06 583) IJ07, IJ10, IJ11, IJ14 584) IJ16, IJ22, IJ23, IJ25 585) IJ28, IJ31, IJ32, IJ33 586) IJ34, IJ35, IJ36, IJ39 587) IJ40, IJ41

Part of the actuator moves to shut off the inlet	The actuator and a wall of the ink chamber are arranged so that the motion of the actuator closes off the inlet.	588) Significant reductions in back-flow can be achieved 589) Compact designs possible	590) Small increase in fabrication complexity	591) IJ07, IJ20, IJ26, IJ38
Nozzle actuator does not result in ink back-flow	In some configurations of ink jet, there is no expansion or movement of an actuator which may cause ink back-flow through the inlet.	592) Ink back-flow problem is eliminated	593) None related to ink back-flow on actuation	594) Silverbrook, EP 0771 658 A2 and related patent applications 595) Valve-jet 596) Tone-jet 597) IJ08, IJ13, IJ15, IJ17 598) IJ18, IJ19, IJ21

NOZZLE CLEARING METHOD

Nozzle Clearing method	Description	Advantages	Disadvantages	Examples
Normal nozzle firing	All of the nozzles are fired periodically, before the ink has a chance to dry. When not in use the nozzles are sealed (capped) against air. The nozzle firing is usually performed during a special clearing cycle, after first moving the print head to a cleaning station.	599) No added complexity on the print head	600) May not be sufficient to displace dried ink	601) Most ink jet systems 602) IJ01- IJ07, IJ09- IJ12 603) IJ14, IJ16, IJ20, IJ22 604) IJ23- IJ34, IJ36- IJ45
Extra power to ink heater	In systems which heat the ink, but do not boil it under normal situations, nozzle clearing can be achieved by over-powering the heater and boiling ink at the nozzle.	605) Can be highly effective if the heater is adjacent to the nozzle	606) Requires higher drive voltage for clearing 607) May require larger drive transistors	608) Silverbrook, EP 0771 658 A2 and related patent applications
Rapid succession of actuator pulses	The actuator is fired in rapid succession. In some configurations, this may cause heat build-up at the nozzle which boils the ink, clearing the nozzle. In other situations, it may cause sufficient vibrations to dislodge clogged nozzles.	609) Does not require extra drive circuits on the print head 610) Can be readily controlled and initiated by digital logic	611) Effectiveness depends substantially upon the configuration of the inkjet nozzle	612) May be used with: 613) IJ01-IJ07, IJ09- IJ11 614) IJ14, IJ16, IJ20, IJ22 615) IJ23-IJ25, IJ27- IJ34 616) IJ36-IJ45

Extra power to ink pushing actuator	Where an actuator is not normally driven to the limit of its motion, nozzle clearing may be assisted by providing an enhanced drive signal to the actuator.	617) A simple solution where applicable	618) Not suitable where there is a hard limit to actuator movement	619) May be used with: 620) IJ03, IJ09, IJ16, IJ20 621) IJ23, IJ24, IJ25, IJ27 622) IJ29, IJ30, IJ31, IJ32 623) IJ39, IJ40, IJ41, IJ42 624) IJ43, IJ44, IJ45
Acoustic resonance	An ultrasonic wave is applied to the ink chamber. This wave is of an appropriate amplitude and frequency to cause sufficient force at the nozzle to clear blockages. This is easiest to achieve if the ultrasonic wave is at a resonant frequency of the ink cavity.	625) A high nozzle clearing capability can be achieved 626) May be implemented at very low cost in systems which already include acoustic actuators	627) High implementation cost if system does not already include an acoustic actuator	628) IJ08, IJ13, IJ15, IJ17 629) IJ18, IJ19, IJ21
Nozzle clearing plate	A microfabricated plate is pushed against the nozzles. The plate has a post for every nozzle. The array of posts	630) Can clear severely clogged nozzles	631) Accurate mechanical alignment is required 632) Moving parts are required 633) There is risk of damage to the nozzles 634) Accurate fabrication is required	635) Silverbrook, EP 0771 658 A2 and related patent applications
Ink pressure pulse	The pressure of the ink is temporarily increased so that ink streams from all of the nozzles. This may be used in conjunction with actuator energizing.	636) May be effective where other methods cannot be used	637) Requires pressure pump or other pressure actuator 638) Expensive 639) Wasteful of ink	640) May be used with all IJ series ink jets
Print head wiper	A flexible 'blade' is wiped across the print head surface. The blade is usually fabricated from a flexible polymer, e.g. rubber or synthetic elastomer.	641) Effective for planar print head surfaces 642) Low cost	643) Difficult to use if print head surface is non-planar or very fragile 644) Requires mechanical parts 645) Blade can wear out in high volume print systems	646) Many ink jet systems

Separate ink boiling heater	A separate heater is provided at the nozzle although the normal drop e–ection mechanism does not require it. The heaters do not require individual drive circuits, as many nozzles can be cleared simultaneously, and no imaging is required.	647) Can be effective where other nozzle clearing methods cannot be used 648) Can be implemented at no additional cost in some inkjet configurations	649) Fabrication complexity	650) Can be used with many IJ series ink jets

NOZZLE PLATE CONSTRUCTION

Nozzle plate construction	Description	Advantages	Disadvantages	Examples
Electroformed nickel	A nozzle plate is separately fabricated from electroformed nickel, and bonded to the print head ~~chip~~integrated circuit.	651) Fabrication simplicity	652) High temperatures and pressures are required to bond nozzle plate 653) Minimum thickness constraints 654) Differential thermal expansion	655) Hewlett Packard Thermal Inkjet
Laser ablated or drilled polymer	Individual nozzle holes are ablated by an intense UV laser in a nozzle plate, which is typically a polymer such as polyimide or polysulphone	656) No masks required 657) Can be quite fast 658) Some control over nozzle profile is possible 659) Equipment required is relatively low cost	660) Each hole must be individually formed 661) Special equipment required 662) Slow where there are many thousands of nozzles per print head 663) May produce thin burrs at exit holes	664) Canon Bubblejet 665) 1988 Sercel et al., SPIE, Vol. 998 Excimer Beam Applications, pp. 76-83 666) 1993 Watanabe et al., USP 5,208,604
Silicon micro-machined	A separate nozzle plate is micromachined from single crystal silicon, and bonded to the print head wafer.	667) High accuracy is attainable	668) Two part construction 669) High cost 670) Requires precision alignment 671) Nozzles may be clogged by adhesive	672) K. Bean, IEEE Transactions on Electron Devices, Vol. ED-25, No. 10, 1978, pp 1185-1195 673) Xerox 1990 Hawkins et al., USP 4,899,181
Glass capillaries	Fine glass capillaries are drawn from glass tubing. This method has been used for making individual nozzles, but is difficult to use for bulk manufacturing of print heads with thousands of nozzles.	674) No expensive equipment required 675) Simple to make single nozzles	676) Very small nozzle sizes are difficult to form 677) Not suited for mass production	678) 1970 Zoltan USP 3,683,212

Monolithic, surface micro-machined using VLSI lithographic processes	The nozzle plate is deposited as a layer using standard VLSI deposition techniques. Nozzles are etched in the nozzle plate using VLSI lithography and etching.	679) High accuracy (<1 μm) 680) Monolithic 681) Low cost 682) Existing processes can be used	683) Requires sacrificial layer under the nozzle plate to form the nozzle chamber 684) Surface may be fragile to the touch	685) Silverbrook, EP 0771 658 A2 and related patent applications 686) IJ01, IJ02, IJ04, IJ11 687) IJ12, IJ17, IJ18, IJ20 688) IJ22, IJ24, IJ27, IJ28 689) IJ29, IJ30, IJ31, IJ32 690) IJ33, IJ34, IJ36, IJ37 691) IJ38, IJ39, IJ40, IJ41 692) IJ42, IJ43, IJ44
Monolithic, etched through substrate	The nozzle plate is a buried etch stop in the wafer. Nozzle chambers are etched in the front of the wafer, and the wafer is thinned from the back side. Nozzles are then etched in the etch stop layer.	693) High accuracy (<1 μm) 694) Monolithic 695) Low cost 696) No differential expansion	697) Requires long etch times 698) Requires a support wafer	699) IJ03, IJ05, IJ06, IJ07 700) IJ08, IJ09, IJ10, IJ13 701) IJ14, IJ15, IJ16, IJ19 702) IJ21, IJ23, IJ25, IJ26
No nozzle plate	Various methods have been tried to eliminate the nozzles entirely, to prevent nozzle clogging. These include thermal bubble mechanisms and acoustic lens mechanisms	703) No nozzles to become clogged	704) Difficult to control drop position accurately 705) Crosstalk problems	706) Ricoh 1995 Sekiya et al USP 5,412,413 707) 1993 Hadimioglu et al EUP 550,192 708) 1993 Elrod et al EUP 572,220

Trough	Each drop ejector has a trough through which a paddle moves. There is no nozzle plate.	709) Reduced manufacturing complexity 710) Monolithic	711) Drop firing direction is sensitive to wicking.	712) IJ35
Nozzle slit instead of individual nozzles	The elimination of nozzle holes and replacement by a slit encompassing many actuator positions reduces nozzle clogging, but increases crosstalk due to ink surface waves	713) No nozzles to become clogged	714) Difficult to control drop position accurately 715) Crosstalk problems	716) 1989 Saito et al USP 4,799,068

DROP EJECTION DIRECTION

Ejection direction	Description	Advantages	Disadvantages	Examples
Edge **('edge shooter')**	Ink flow is along the surface of the ~~chip~~integrated circuit, and ink drops are ejected from the ~~chip~~integrated circuit edge.	717) Simple construction 718) No silicon etching required 719) Good heat sinking via substrate 720) Mechanically strong 721) Ease of ~~chip~~integrated circuit handing	722) Nozzles limited to edge 723) High resolution is difficult 724) Fast color printing requires one print head per color	725) Canon Bubblejet 1979 Endo et al GB patent 2,007,162 726) Xerox heater-in-pit 1990 Hawkins et al USP 4,899,181 727) Tone-jet
Surface **('roof shooter')**	Ink flow is along the surface of the ~~chip~~integrated circuit, and ink drops are ejected from the ~~chip~~integrated circuit surface, normal to the plane of the ~~chip~~integrated circuit.	728) No bulk silicon etching required 729) Silicon can make an effective heat sink 730) Mechanical strength	731) Maximum ink flow is severely restricted	732) Hewlett-Packard TIJ 1982 Vaught et al USP 4,490,728 733) IJ02, IJ11, IJ12, IJ20 734) IJ22
Through ~~chip~~integrated circuit, forward **('up shooter')**	Ink flow is through the ~~chip~~integrated circuit, and ink drops are ejected from the front surface of the ~~chip~~integrated circuit.	735) High ink flow 736) Suitable for pagewidth print 737) High nozzle packing density therefore low manufacturing cost	738) Requires bulk silicon etching	739) Silverbrook, EP 0771 658 A2 and related patent applications 740) IJ04, IJ17, IJ18, IJ24 741) IJ27-IJ45

Through ~~chip~~integrated circuit, reverse ('down shooter')	Ink flow is through the ~~chip~~integrated circuit, and ink drops are ejected from the rear surface of the ~~chip~~integrated circuit.	742) High ink flow 743) Suitable for pagewidth print 744) High nozzle packing density therefore low manufacturing cost	745) Requires wafer thinning 746) Requires special handling during manufacture	747) IJ01, IJ03, IJ05, IJ06 748) IJ07, IJ08, IJ09, IJ10 749) IJ13, IJ14, IJ15, IJ16 750) IJ19, IJ21, IJ23, IJ25 751) IJ26
Through actuator	Ink flow is through the actuator, which is not fabricated as part of the same substrate as the drive transistors.	752) Suitable for piezoelectric print heads	753) Pagewidth print heads require several thousand connections to drive circuits 754) Cannot be manufactured in standard CMOS fabs 755) Complex assembly required	756) Epson Stylus 757) Tektronix hot melt piezoelectric ink jets

INK TYPE

Ink type	Description	Advantages	Disadvantages	Examples
Aqueous, dye	Water based ink which typically contains: water, dye, surfactant, humectant, and biocide. Modern ink dyes have high water-fastness, light fastness	758) Environmentally friendly 759) No odor	760) Slow drying 761) Corrosive 762) Bleeds on paper 763) May strikethrough 764) Cockles paper	765) Most existing inkjets 766) All IJ series ink jets 767) Silverbrook, EP 0771 658 A2 and related patent applications
Aqueous, pigment	Water based ink which typically contains: water, pigment, surfactant, humectant, and biocide. Pigments have an advantage in reduced bleed, wicking and strikethrough.	768) Environmentally friendly 769) No odor 770) Reduced bleed 771) Reduced wicking 772) Reduced strikethrough	773) Slow drying 774) Corrosive 775) Pigment may clog nozzles 776) Pigment may clog actuator mechanisms 777) Cockles paper	778) IJ02, IJ04, IJ21, IJ26 779) IJ27, IJ30 780) Silverbrook, EP 0771 658 A2 and related patent applications 781) Piezoelectric ink-jets 782) Thermal ink jets (with significant restrictions)
Methyl Ethyl Ketone (MEK)	MEK is a highly volatile solvent used for industrial printing on difficult surfaces such as aluminum cans.	783) Very fast drying 784) Prints on various substrates such as metals and plastics	785) Odorous 786) Flammable	787) All IJ series ink jets
Alcohol (ethanol, 2-butanol, and others)	Alcohol based inks can be used where the printer must operate at temperatures below the freezing point of water. An example of this is in-camera consumer photographic printing.	788) Fast drying 789) Operates at sub-freezing temperatures 790) Reduced paper cockle 791) Low cost	792) Slight odor 793) Flammable	794) All IJ series ink jets

Phase change (hot melt)	The ink is solid at room temperature, and is melted in the print head before jetting. Hot melt inks are usually wax based, with a melting point around 80 °C. After jetting the ink freezes almost instantly upon contacting the print medium or a transfer roller.	795) No drying time- ink instantly freezes on the print medium 796) Almost any print medium can be used 797) No paper cockle occurs 798) No wicking occurs 799) No bleed occurs 800) No strikethrough occurs	801) High viscosity 802) Printed ink typically has a 'waxy' feel 803) Printed pages may 'block' 804) Ink temperature may be above the curie point of permanent magnets 805) Ink heaters consume power 806) Long warm-up time	807) Tektronix hot melt piezoelectric ink jets 808) 1989 Nowak USP 4,820,346 809) All IJ series ink jets
Oil	Oil based inks are extensively used in offset printing. They have advantages in improved characteristics on paper (especially no wicking or cockle). Oil soluble dies and pigments are required.	810) High solubility medium for some dyes 811) Does not cockle paper 812) Does not wick through paper	813) High viscosity: this is a significant limitation for use in inkjets, which usually require a low viscosity. Some short chain and multi-branched oils have a sufficiently low viscosity. 814) Slow drying	815) All IJ series ink jets
Microemulsion	A microemulsion is a stable, self forming emulsion of oil, water, and surfactant. The characteristic drop size is less than 100 nm, and is determined by the preferred curvature of the surfactant.	816) Stops ink bleed 817) High dye solubility 818) Water, oil, and amphiphilic soluble dies can be used 819) Can stabilize pigment suspensions	820) Viscosity higher than water 821) Cost is slightly higher than water based ink 822) High surfactant concentration required (around 5%)	823) All IJ series ink jets

Ink Jet Printing

A large number of new forms of ink jet printers have been developed to facilitate alternative ink jet technologies for the image processing and data distribution system. Various combinations of ink jet devices can be included in printer devices incorporated as part of the present invention. Australian Provisional Patent Applications relating to these ink jets which are specifically incorporated by cross reference. The serial numbers of respective corresponding US patent applications are also provided for the sake of convenience.

Australian Provisional Number	Filing Date	Title	US Patent/Patent Application and Filing Date
PO8066	15-Jul-97	Image Creation Method and Apparatus (IJ01)	6,227,652 (July 10, 1998)
PO8072	15-Jul-97	Image Creation Method and Apparatus (IJ02)	6,213,588 (July 10, 1998)
PO8040	15-Jul-97	Image Creation Method and Apparatus (IJ03)	6,213,589 (July 10, 1998)
PO8071	15-Jul-97	Image Creation Method and Apparatus (IJ04)	6,231,163 (July 10, 1998)
PO8047	15-Jul-97	Image Creation Method and Apparatus (IJ05)	6,247,795 (July 10, 1998)
PO8035	15-Jul-97	Image Creation Method and Apparatus (IJ06)	6,394,581 (July 10, 1998)
PO8044	15-Jul-97	Image Creation Method and Apparatus (IJ07)	6,244,691 (July 10, 1998)
PO8063	15-Jul-97	Image Creation Method and Apparatus (IJ08)	6,257,704 (July 10, 1998)
PO8057	15-Jul-97	Image Creation Method and Apparatus (IJ09)	6,416,168 (July 10, 1998)
PO8056	15-Jul-97	Image Creation Method and Apparatus (IJ10)	6,220,694 (July 10, 1998)
PO8069	15-Jul-97	Image Creation Method and Apparatus (IJ11)	6,257,705 (July 10, 1998)
PO8049	15-Jul-97	Image Creation Method and Apparatus (IJ12)	6,247,794 (July 10, 1998)
PO8036	15-Jul-97	Image Creation Method and Apparatus (IJ13)	6,234,610 (July 10, 1998)
PO8048	15-Jul-97	Image Creation Method and Apparatus (IJ14)	6,247,793 (July 10, 1998)
PO8070	15-Jul-97	Image Creation Method and Apparatus (IJ15)	6,264,306 (July 10, 1998)
PO8067	15-Jul-97	Image Creation Method and Apparatus (IJ16)	6,241,342 (July 10, 1998)
PO8001	15-Jul-97	Image Creation Method and Apparatus (IJ17)	6,247,792 (July 10, 1998)
PO8038	15-Jul-97	Image Creation Method and Apparatus (IJ18)	6,264,307 (July 10, 1998)
PO8033	15-Jul-97	Image Creation Method and Apparatus (IJ19)	6,254,220 (July 10, 1998)
PO8002	15-Jul-97	Image Creation Method and Apparatus (IJ20)	6,234,611

			(July 10, 1998)
PO8068	15-Jul-97	Image Creation Method and Apparatus (IJ21)	6,302,528) (July 10, 1998)
PO8062	15-Jul-97	Image Creation Method and Apparatus (IJ22)	6,283,582 (July 10, 1998)
PO8034	15-Jul-97	Image Creation Method and Apparatus (IJ23)	6,239,821 (July 10, 1998)
PO8039	15-Jul-97	Image Creation Method and Apparatus (IJ24)	6,338,547 (July 10, 1998)
PO8041	15-Jul-97	Image Creation Method and Apparatus (IJ25)	6,247,796 (July 10, 1998)
PO8004	15-Jul-97	Image Creation Method and Apparatus (IJ26)	09/113,122 (July 10, 1998)
PO8037	15-Jul-97	Image Creation Method and Apparatus (IJ27)	6,390,603 (July 10, 1998)
PO8043	15-Jul-97	Image Creation Method and Apparatus (IJ28)	6,362,843 (July 10, 1998)
PO8042	15-Jul-97	Image Creation Method and Apparatus (IJ29)	6,293,653 (July 10, 1998)
PO8064	15-Jul-97	Image Creation Method and Apparatus (IJ30)	6,312,107 (July 10, 1998)
PO9389	23-Sep-97	Image Creation Method and Apparatus (IJ31)	6,227,653 (July 10, 1998)
PO9391	23-Sep-97	Image Creation Method and Apparatus (IJ32)	6,234,609 (July 10, 1998)
PP0888	12-Dec-97	Image Creation Method and Apparatus (IJ33)	6,238,040 (July 10, 1998)
PP0891	12-Dec-97	Image Creation Method and Apparatus (IJ34)	6,188,415 (July 10, 1998)
PP0890	12-Dec-97	Image Creation Method and Apparatus (IJ35)	6,227,654 (July 10, 1998)
PP0873	12-Dec-97	Image Creation Method and Apparatus (IJ36)	6,209,989 (July 10, 1998)
PP0993	12-Dec-97	Image Creation Method and Apparatus (IJ37)	6,247,791 (July 10, 1998)
PP0890	12-Dec-97	Image Creation Method and Apparatus (IJ38)	6,336,710 (July 10, 1998)
PP1398	19-Jan-98	An Image Creation Method and Apparatus (IJ39)	6,217,153 (July 10, 1998)
PP2592	25-Mar-98	An Image Creation Method and Apparatus (IJ40)	6,416,167 (July 10, 1998)
PP2593	25-Mar-98	Image Creation Method and Apparatus (IJ41)	6,243,113 (July 10, 1998)
PP3991	9-Jun-98	Image Creation Method and Apparatus (IJ42)	6,283,581 (July 10, 1998)
PP3987	9-Jun-98	Image Creation Method and Apparatus (IJ43)	6,247,790 (July 10, 1998)
PP3985	9-Jun-98	Image Creation Method and Apparatus (IJ44)	6,260,953 (July 10, 1998)
PP3983	9-Jun-98	Image Creation Method and Apparatus (IJ45)	6,267,469 (July 10, 1998)

Ink Jet Manufacturing

Further, the present application may utilize advanced semiconductor fabrication techniques in the construction of large arrays of ink jet printers. Suitable manufacturing techniques are described in the following Australian provisional patent specifications incorporated here by cross-reference. The serial numbers of respective corresponding US patent applications are also provided for the sake of convenience.

Australian Provisional Number	Filing Date	Title	US Patent/Patent Application and Filing Date
PO7935	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM01)	6,224,780 (July 10, 1998)
PO7936	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM02)	6,235,212 (July 10, 1998)
PO7937	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM03)	6,280,643 (July 10, 1998)
PO8061	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM04)	6,284,147 (July 10, 1998)
PO8054	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM05)	6,214,244 (July 10, 1998)
PO8065	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM06)	6,071,750 (July 10, 1998)
PO8055	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM07)	6,267,905 (July 10, 1998)
PO8053	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM08)	6,251,298 (July 10, 1998)
PO8078	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM09)	6,258,285 (July 10, 1998)
PO7933	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM10)	6,225,138 (July 10, 1998)
PO7950	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM11)	6,241,904 (July 10, 1998)
PO7949	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM12)	6,299,786 (July 10, 1998)
PO8060	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM13)	09/113,124 (July 10, 1998)
PO8059	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM14)	6,231,773 (July 10, 1998)
PO8073	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM15)	6,190,931 (July 10, 1998)
PO8076	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM16)	6,248,249 (July 10, 1998)
PO8075	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM17)	6,290,862 (July 10, 1998)
PO8079	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM18)	6,241,906 (July 10, 1998)

PO8050	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM19)	09/113,116 (July 10, 1998)
PO8052	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM20)	6,241,905 (July 10, 1998)
PO7948	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM21)	6,451,216 (July 10, 1998)
PO7951	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM22)	6,231,772 (July 10, 1998)
PO8074	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM23)	6,274,056 (July 10, 1998)
PO7941	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM24)	6,290,861 (July 10, 1998)
PO8077	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM25)	6,248,248 (July 10, 1998)
PO8058	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM26)	6,306,671 (July 10, 1998)
PO8051	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM27)	6,331,258 (July 10, 1998)
PO8045	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM28)	6,110,754 (July 10, 1998)
PO7952	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM29)	6,294,101 (July 10, 1998)
PO8046	15-Jul-97	A Method of Manufacture of an Image Creation Apparatus (IJM30)	6,416,679 (July 10, 1998)
PO8503	11-Aug-97	A Method of Manufacture of an Image Creation Apparatus (IJM30a)	6,264,849 (July 10, 1998)
PO9390	23-Sep-97	A Method of Manufacture of an Image Creation Apparatus (IJM31)	6,254,793 (July 10, 1998)
PO9392	23-Sep-97	A Method of Manufacture of an Image Creation Apparatus (IJM32)	6,235,211 (July 10, 1998)
PP0889	12-Dec-97	A Method of Manufacture of an Image Creation Apparatus (IJM35)	6,235,211 (July 10, 1998)
PP0887	12-Dec-97	A Method of Manufacture of an Image Creation Apparatus (IJM36)	6,264,850 (July 10, 1998)
PP0882	12-Dec-97	A Method of Manufacture of an Image Creation Apparatus (IJM37)	6,258,284 (July 10, 1998)
PP0874	12-Dec-97	A Method of Manufacture of an Image Creation Apparatus (IJM38)	6,258,284 (July 10, 1998)
PP1396	19-Jan-98	A Method of Manufacture of an Image Creation Apparatus (IJM39)	6,228,668 (July 10, 1998)
PP2591	25-Mar-98	A Method of Manufacture of an Image Creation Apparatus (IJM41)	6,180,427 (July 10, 1998)
PP3989	9-Jun-98	A Method of Manufacture of an Image Creation Apparatus (IJM40)	6,171,875 (July 10, 1998)
PP3990	9-Jun-98	A Method of Manufacture of an Image Creation Apparatus (IJM42)	6,267,904 (July 10, 1998)
PP3986	9-Jun-98	A Method of Manufacture of an Image Creation Apparatus (IJM43)	6,245,247 (July 10, 1998)
PP3984	9-Jun-98	A Method of Manufacture of an Image Creation Apparatus (IJM44)	6,245,247 (July 10, 1998)

		Apparatus (IJM44)	
PP3982	9-Jun-98	A Method of Manufacture of an Image Creation Apparatus (IJM45)	6,231,148 (July 10, 1998)

Fluid Supply

Further, the present application may utilize an ink delivery system to the ink jet head. Delivery systems relating to the supply of ink to a series of ink jet nozzles are described in the following Australian provisional patent specifications, the disclosure of which are hereby incorporated by cross-reference. The serial numbers of respective corresponding US patent applications are also provided for the sake of convenience.

Australian Provisional Number	Filing Date	Title	US Patent/Patent Application and Filing Date
PO8003	15-Jul-97	Supply Method and Apparatus (F1)	6,350,023 (July 10, 1998)
PO8005	15-Jul-97	Supply Method and Apparatus (F2)	6,318,849 (July 10, 1998)
PO9404	23-Sep-97	A Device and Method (F3)	09/113,101 (July 10, 1998)

MEMS Technology

Further, the present application may utilize advanced semiconductor microelectromechanical techniques in the construction of large arrays of ink jet printers. Suitable microelectromechanical techniques are described in the following Australian provisional patent specifications incorporated here by cross-reference. The serial numbers of respective corresponding US patent applications are also provided for the sake of convenience.

Australian Provisional Number	Filing Date	Title	US Patent/Patent Application and Filing Date
PO7943	15-Jul-97	A device (MEMS01)	
PO8006	15-Jul-97	A device (MEMS02)	6,087,638 (July 10, 1998)
PO8007	15-Jul-97	A device (MEMS03)	09/113,093 (July 10, 1998)
PO8008	15-Jul-97	A device (MEMS04)	6,340,222 (July 10, 1998)
PO8010	15-Jul-97	A device (MEMS05)	6,041,600 (July 10, 1998)
PO8011	15-Jul-97	A device (MEMS06)	6,299,300 (July 10, 1998)
PO7947	15-Jul-97	A device (MEMS07)	6,067,797 (July 10, 1998)
PO7945	15-Jul-97	A device (MEMS08)	09/113,081 (July 10, 1998)
PO7944	15-Jul-97	A device (MEMS09)	6,286,935 (July 10, 1998)
PO7946	15-Jul-97	A device (MEMS10)	6,044,646 (July 10, 1998)
PO9393	23-Sep-97	A Device and Method (MEMS11)	09/113,065 (July 10, 1998)
PP0875	12-Dec-97	A Device (MEMS12)	09/113,078 (July 10, 1998)
PP0894	12-Dec-97	A Device and Method (MEMS13)	09/113,075 (July 10, 1998)

IR Technologies

Further, the present application may include the utilization of a disposable camera system such as those described in the following Australian provisional patent specifications incorporated here by cross-reference. The serial numbers of respective corresponding US patent applications are also provided for the sake of convenience.

Australian Provisional Number	Filing Date	Title	US Patent/Patent Application and Filing Date
PP0895	12-Dec-97	An Image Creation Method and Apparatus (IR01)	6,231,148 (July 10, 1998)
PP0870	12-Dec-97	A Device and Method (IR02)	09/113,106 (July 10, 1998)
PP0869	12-Dec-97	A Device and Method (IR04)	6,293,658 (July 10, 1998)
PP0887	12-Dec-97	Image Creation Method and Apparatus (IR05)	09/113,104 (July 10, 1998)
PP0885	12-Dec-97	An Image Production System (IR06)	6,238,033 (July 10, 1998)
PP0884	12-Dec-97	Image Creation Method and Apparatus (IR10)	6,312,070 (July 10, 1998)
PP0886	12-Dec-97	Image Creation Method and Apparatus (IR12)	6,238,111 (July 10, 1998)
PP0871	12-Dec-97	A Device and Method (IR13)	09/113,086 (July 10, 1998)
PP0876	12-Dec-97	An Image Processing Method and Apparatus (IR14)	09/113,094 (July 10, 1998)
PP0877	12-Dec-97	A Device and Method (IR16)	6,378,970 (July 10, 1998
PP0878	12-Dec-97	A Device and Method (IR17)	6,196,739 (July 10, 1998)
PP0879	12-Dec-97	A Device and Method (IR18)	09/112,774 (July 10, 1998)
PP0883	12-Dec-97	A Device and Method (IR19)	6,270,182 (July 10, 1998)
PP0880	12-Dec-97	A Device and Method (IR20)	6,152,619 (July 10, 1998)
PP0881	12-Dec-97	A Device and Method (IR21)	09/113,092 (July 10, 1998)

DotCard Technologies

Further, the present application may include the utilization of a data distribution system such as that described in the following Australian provisional patent specifications incorporated here by cross-reference. The serial numbers of respective corresponding US patent applications are also provided for the sake of convenience.

Australian Provisional Number	Filing Date	Title	US Patent/Patent Application and Filing Date
PP2370	16-Mar-98	Data Processing Method and Apparatus (Dot01)	09/112,781 (July 10, 1998)
PP2371	16-Mar-98	Data Processing Method and Apparatus (Dot02)	09/113,052 (July 10, 1998

Artcam Technologies

Further, the present application may include the utilization of camera and data processing techniques such as an Artcam type device as described in the following Australian provisional patent specifications incorporated here by cross-reference. The serial numbers of respective corresponding US patent applications are also provided for the sake of convenience.

Australian Provisional Number	Filing Date	Title	US Patent/Patent Application and Filing Date
PO7991	15-Jul-97	Image Processing Method and Apparatus (ART01)	09/113,060 (July 10, 1998)
PO7988	15-Jul-97	Image Processing Method and Apparatus (ART02)	6,476,863 (July 10, 1998)
PO7993	15-Jul-97	Image Processing Method and Apparatus (ART03)	09/113,073 (July 10, 1998)
PO9395	23-Sep-97	Data Processing Method and Apparatus (ART04)	6,322,181 (July 10, 1998)
PO8017	15-Jul-97	Image Processing Method and Apparatus (ART06)	09/112,747 (July 10, 1998)
PO8014	15-Jul-97	Media Device (ART07)	6,227,648 (July 10, 1998)
PO8025	15-Jul-97	Image Processing Method and Apparatus (ART08)	09/112,750 (July 10, 1998)
PO8032	15-Jul-97	Image Processing Method and Apparatus (ART09)	09/112,746 (July 10, 1998)
PO7999	15-Jul-97	Image Processing Method and Apparatus (ART10)	09/112,743 (July 10, 1998)
PO7998	15-Jul-97	Image Processing Method and Apparatus (ART11)	09/112,742 (July 10, 1998)
PO8031	15-Jul-97	Image Processing Method and Apparatus (ART12)	09/112,741 (July 10, 1998)
PO8030	15-Jul-97	Media Device (ART13)	6,196,541 (July 10, 1998)
PO7997	15-Jul-97	Media Device (ART15)	6,195,150 (July 10, 1998)
PO7979	15-Jul-97	Media Device (ART16)	6,362,868

			(July 10, 1998)
PO8015	15-Jul-97	Media Device (ART17)	09/112,738 (July 10, 1998)
PO7978	15-Jul-97	Media Device (ART18)	09/113,067 (July 10, 1998)
PO7982	15-Jul-97	Data Processing Method and Apparatus (ART19)	6,431,669 (July 10, 1998
PO7989	15-Jul-97	Data Processing Method and Apparatus (ART20)	6,362,869 (July 10, 1998
PO8019	15-Jul-97	Media Processing Method and Apparatus (ART21)	6,472,052 (July 10, 1998
PO7980	15-Jul-97	Image Processing Method and Apparatus (ART22)	6,356,715 (July 10, 1998)
PO8018	15-Jul-97	Image Processing Method and Apparatus (ART24)	09/112,777 (July 10, 1998)
PO7938	15-Jul-97	Image Processing Method and Apparatus (ART25)	09/113,224 (July 10, 1998)
PO8016	15-Jul-97	Image Processing Method and Apparatus (ART26)	6,366,693 (July 10, 1998)
PO8024	15-Jul-97	Image Processing Method and Apparatus (ART27)	6,329,990 (July 10, 1998)
PO7940	15-Jul-97	Data Processing Method and Apparatus (ART28)	09/113,072 (July 10, 1998)
PO7939	15-Jul-97	Data Processing Method and Apparatus (ART29)	09/112,785 (July 10, 1998)
PO8501	11-Aug-97	Image Processing Method and Apparatus (ART30)	6,137,500 (July 10, 1998)
PO8500	11-Aug-97	Image Processing Method and Apparatus (ART31)	09/112,796 (July 10, 1998)
PO7987	15-Jul-97	Data Processing Method and Apparatus (ART32)	09/113,071 (July 10, 1998)
PO8022	15-Jul-97	Image Processing Method and Apparatus (ART33)	6,398,328 (July 10, 1998
PO8497	11-Aug-97	Image Processing Method and Apparatus (ART34)	09/113,090 (July 10, 1998)
PO8020	15-Jul-97	Data Processing Method and Apparatus (ART38)	6,431,704 (July 10, 1998
PO8023	15-Jul-97	Data Processing Method and Apparatus (ART39)	09/113,222 (July 10, 1998)
PO8504	11-Aug-97	Image Processing Method and Apparatus (ART42)	09/112,786 (July 10, 1998)
PO8000	15-Jul-97	Data Processing Method and Apparatus (ART43)	6,415,054 (July 10, 1998)
PO7977	15-Jul-97	Data Processing Method and Apparatus (ART44)	09/112,782 (July 10, 1998)
PO7934	15-Jul-97	Data Processing Method and Apparatus (ART45)	09/113,056 (July 10, 1998)
PO7990	15-Jul-97	Data Processing Method and Apparatus (ART46)	09/113,059 (July 10, 1998)
PO8499	11-Aug-97	Image Processing Method and Apparatus (ART47)	6,486,886 (July 10, 1998)
PO8502	11-Aug-97	Image Processing Method and Apparatus (ART48)	6,381,361 (July 10, 1998)
PO7981	15-Jul-97	Data Processing Method and Apparatus (ART50)	6,317,192 (July 10, 1998
PO7986	15-Jul-97	Data Processing Method and Apparatus (ART51)	09/113,057 (July 10, 1998)
PO7983	15-Jul-97	Data Processing Method and Apparatus	09/113,054

		(ART52)	(July 10, 1998)
PO8026	15-Jul-97	Image Processing Method and Apparatus (ART53)	09/112,752 (July 10, 1998)
PO8027	15-Jul-97	Image Processing Method and Apparatus (ART54)	09/112,759 (July 10, 1998)
PO8028	15-Jul-97	Image Processing Method and Apparatus (ART56)	09/112,757 (July 10, 1998)
PO9394	23-Sep-97	Image Processing Method and Apparatus (ART57)	6,357,135 (July 10, 1998
PO9396	23-Sep-97	Data Processing Method and Apparatus (ART58)	09/113,107 (July 10, 1998)
PO9397	23-Sep-97	Data Processing Method and Apparatus (ART59)	6,271,931 (July 10, 1998)
PO9398	23-Sep-97	Data Processing Method and Apparatus (ART60)	6,353,772 (July 10, 1998)
PO9399	23-Sep-97	Data Processing Method and Apparatus (ART61)	6,106,147 (July 10, 1998)
PO9400	23-Sep-97	Data Processing Method and Apparatus (ART62)	09/112,790 (July 10, 1998)
PO9401	23-Sep-97	Data Processing Method and Apparatus (ART63)	6,304,291 (July 10, 1998)
PO9402	23-Sep-97	Data Processing Method and Apparatus (ART64)	09/112,788 (July 10, 1998)
PO9403	23-Sep-97	Data Processing Method and Apparatus (ART65)	6,305,770 (July 10, 1998)
PO9405	23-Sep-97	Data Processing Method and Apparatus (ART66)	6,289,262 (July 10, 1998)
PP0959	16-Dec-97	A Data Processing Method and Apparatus (ART68)	6,315,200 (July 10, 1998)
PP1397	19-Jan-98	A Media Device (ART69)	6,217,165 (July 10, 1998)

We Claim:

1. A printhead assembly for a camera system having a chassis and a platen assembly that is mountable on the chassis, the platen assembly being configured to support passage of a print medium along a printing path, the printhead assembly comprising

an ink reservoir assembly that is mountable on the chassis and defines at least three ink reservoirs in which respective differently colored inks are received, the ink reservoir assembly defining an outlet;

a guide assembly that is positioned in the ink reservoir assembly to define at least three discrete ink paths that open at the outlet; and

at least one printhead integrated circuit that is positioned in the outlet to span the printing path, the, or each, printhead integrated circuit defining at least three sets of inlet apertures, each set of inlet apertures being aligned with a respective ink path.

2. A printhead assembly as claimed in claim 1, in which the ink reservoir assembly defines three ink reservoirs and the guide assembly defines three discrete ink paths.

3. A printhead assembly as claimed in claim 2, in which both the ink reservoir assembly and the guide assembly are elongate to span the printing path, the ink reservoir assembly including an elongate base member and an elongate cover member, the cover member having a roof wall, a pair of opposed side walls and a pair of spaced inner walls, the side walls and the inner walls depending from the roof wall and being generally parallel to each other and the base member having a floor and a pair of opposed end walls and defining an elongate opening in which the printhead integrated circuits are mounted, the guide assembly being interposed between lower ends of the inner walls and the floor.

4. A printhead assembly as claimed in claim 3, in which the guide assembly includes a pair of guide walls that extend from respective lower ends of the inner walls inwardly towards the elongate opening to define the three distinct ink paths that terminate at respective sets of inlet apertures of the printhead integrated circuits.

5. A printhead assembly as claimed in claim 3, in which the base member, the cover member and the guide assembly are molded of a plastics material.

6. A printhead assembly as claimed in claim 3, in which one of the end walls defines a number of air inlet openings that are treated to be hydrophobic to permit the ingress of air into the ink reservoirs as ink is fed from the ink reservoirs and to inhibit the egress of ink.

7. A printhead assembly as claimed in claim 1, in which a sponge-like member is positioned in each ink reservoir to store the ink while inhibiting agitation of ink during general use of the camera system.

8. A camera system that includes a printhead assembly as claimed in claim 1.

Abstract

A printhead assembly for a camera system that includes an ink reservoir assembly that is mountable on the chassis of the camera system and defines at least three ink reservoirs in which differently colored inks are received. The ink reservoir assembly defines an outlet. A guide assembly is positioned in the ink reservoir assembly to define three discrete ink paths that open at the outlet. A printhead integrated circuit is positioned in the outlet to span the printing path. The printhead ~~chip~~integrated circuit defines three sets of inlet apertures, each set of inlet apertures being aligned with a respective ink path.